SCHOOL SCIENCE AND MATHEMATICS

Vol. XXXIII, No.7 October, 1933 Whole No. 288

THE WAY OUT

From every section of the country come reports of curtailment in educational activities as economy measures. On return to school this fall you have found your classes larger, your day longer, the school term shorter, evening and continuation schools eliminated, adult classes discontinued, art, music, domestic science and manual training departments curtailed, essential laboratory instruction abandoned, and even the basic work in mathematics and science attacked as costly and non-essential. You need more maps, charts, and scientific instruments to meet the demands of the larger classes but no appropriation has been made. The reference library needs additional volumes but no funds are available. The textbooks with backs off and leaves out are dirty and falling apart but no provision has been made for a new supply. In many subjects there are not enough books to supply even a single class. Books, too, are probably considered fads and frills. You are expected to accept these conditions cheerfully, do as good teaching as before, and draw a salary (if funds are available) from 25% to 50% lower.

Is all this so-called economy necessary? Have the other state and local institutions suffered such drastic cuts? How much have the salaries of legislators, county and municipal officers, judges, etc. been cut? How many less of them are on the pay rolls? Have the people in your community economized on tobacco and cigarettes, chewing gum and cosmetics? The companies supplying these and other luxuries have been paying dividends to stockholders and high salaries to their officials.

No doubt many of the parents of the boys and girls in your crowded classes do not realize what is going on nor whither it

will lead. School conditions that are now being forced through in the name of economy are bound to lead to increased expenditures for juvenile courts, police, and prisons just a few months later and to industrial slavery within a few years. At present big business interests are being forced into cooperation with a federal government which they are stealthily undermining by destroying the chief guarantee of democracy.

But the case of the schools is not hopeless if we make use of our opportunity. A million teachers are again in charge of over thirty million pupils. Here is opportunity. Is it not time for us to realize that subject matter is not the only important thing and that we have been trying to teach entirely too much of each subject? Why not attempt a smaller amount—whatever can be covered with a fair degree of success? With larger classes pupils must become more self-reliant; the teacher must give more time to inspiration and guidance.

But our opportunity does not end with this vast army of pupils. If we are to rescue public education, we must secure the cooperation of the adult population. Reserve enough time and energy to let parents know what their children are losing by being deprived of text and reference books, tools and apparatus, shops and laboratories. Show the educational loss due to large classes, heavy teacher load, and lack of individual instruction. Lead them to feel responsibility for conditions in the school. Bring them to understand that public education and industrial slavery do not thrive together. Let them know that much of the economy cry is the wail of financial dictators who seek to stem the rising tide of youthful thinkers eager to question the methods and investigate the tax returns of captains of industry. With the cooperation of a community interested in the school and awake to its needs you will be able to wage a winning fight against the allied forces of predatory interests and their political puppets.

ANNOUNCEMENT

The Annual Convention of the Central Association of Science and Mathematics Teachers is the annual reunion of the progressive teachers of science and mathematics in the middle west. This year the meeting will be held in the Congress Hotel in Chicago, December 1st and 2nd. See page 777 of this issue for a preview of the program. Plan now to attend. Organize a party from your community and charter a special car thus getting the advantage of very low rates.

PHOTOPERIODISM: THE REMARKABLE INFLUENCE OF LENGTH-OF-DAY ON PLANT PROCESSES

By Victor A. Greulach
Muskingum College, New Concord, Ohio

I. GARNER AND ALLARD'S DISCOVERY

Back in 1918 if you had gone around the country proclaiming that you could control the growth and time of flowering of almost any plant by simply regulating the length-of-day the botanists and horticulturists would probably have denounced you as a fool or a charlatan. A year or two later their attitude would have been somewhat different, for in 1920 Dr. W. W. Garner and Mr. H. A. Allard, two scientists connected with the government experiment station at Arlington, Virginia, published an epoch-making paper in which they showed beyond reasonable doubt that the length-of-day is the controlling factor in determining when a certain plant will bloom and how it will grow.

Since then, these men and many other investigators have greatly extended our knowledge of this phenomenon until now it is generally recognized that length-of-day controls at least partly, not only flowering and fruiting and growth, but also bulb and tuber formation, leaf-fall and dormancy, senescence and rejuvenescence, sex expression, and indirectly, distribution of plants and of crop producing centers. It is thus evident the discovery is not only one of great significance from a purely scientific viewpoint, but also holds the possibilities of extensive practical application in the fields of agriculture and horticulture. For this control of plant processes by the length-of-day Garner and Allard proposed the term *photoperiodism.*

The discovery of photoperiodism constitutes one of the biggest advances made in the fields of botany and horticulture in the present century; it is certainly the most spectacular. And the entire credit goes to Garner and Allard. Before they began their experiments nobody even suspected such a relationship. It was generally thought that seasonal activities of plants were due to some mysterious inherent rhythm of the plant, or at the most to temperature changes, although this could never be proved. True enough, Prof. L. H. Bailey of Cornell, the French botanist Bonnier, and others had investigated the effect of

added electric arc light and even continuous light on plants away back in the nineties, but they missed the main point entirely.

It was perhaps mere chance that Garner and Allard made the discovery. That is so often the case with outstanding scientific discoveries. Had they not been working with Maryland Mammoth tobacco we might still be wondering why spinach goes to seed in late spring and why leaves fall in the autumn.

The Maryland Mammoth tobacco plant is peculiar in that it grows on and on without flowering, thus producing about 100 leaves to the 25 produced by the parent Maryland Narrowleaf variety before it goes to seed. It was obvious that the Mammoth was a much superior commercial variety, except for the fact that it would not ripen seeds before frost.

Taking some of the plants into the greenhouse, Garner and Allard found that they bloomed in late October or November. This was not so strange, but then the remarkable fact was discovered that seedlings planted in the winter grew no taller than the old Narrowleaf before producing flowers. However, as summer came around the plants assumed their regular tall, flowerless summer form.

Here, then, was something clearly controlled by a seasonal change, so Garner and Allard set out to determine just what the controlling factor was. The three outstanding seasonal changes are in temperature, light intensity, and length-of-day. In this case temperature was evidently not a controlling factor, as the greenhouse was kept at a practically constant temperature. By suitable experiments it was demonstrated that the light intensity did not affect the date of blooming, and the investigators were thus driven to the obvious but astounding conclusion that Maryland Mammoth tobacco would not bloom until the days were suitably short.

These results were so absolutely unbelievable that they then decided to experiment by artificially shortening the day, to determine whether this really was the controlling factor. A small, ventilated, light-proof chamber was provided, in which the plants could be placed for a certain length of time each day. Maryland Mammoth plants started April 14 were put into the chamber July 10 so that they were exposed to only seven hours of light daily, and by August 26 the last plants had begun to flower. Plants set out at the same time but exposed to the full day-length did not bloom until October 7. It thus became quite

evident that it really was the short day which brought the plants into bloom.

Similar experiments were conducted with soy beans. The Bixoli variety had just begun blooming on July 10 when some of the plants were placed in the dark chamber for a few hours each day, while others were allowed the full day-length. On July 30 the seed pods of the test plants were full grown, while those of the check plants exposed to the full day-length were barely half grown. By September 1 the leaves of the test plants were yellowed and falling and many of the seed pods were fully mature, while the leaves and pods of the check plants were still green.

The following year much more extensive tests were made with soy bean, tobacco, and many other plants. A large dark house was built, and tracks were provided so that trucks bearing the test plants could be easily pushed in and out of the building. As a result of these experiments Garner and Allard were able to report that, "The former results were fully confirmed and also considerably extended."

For example, Bixoli soy beans germinated May 17 were placed under a seven-hour day on May 20 and blossomed in 26 days, while the check plants required 110 days. It was also found that a twelve-hour day was as effective as the seven-hour day. This is significant, as Bixoli normally blooms when the days are about that length.

Other varieties of soy beans behaved similarly, although the difference between the test and check plants was not so great. It thus became apparent that the earlier a variety normally blooms the less is the relative effectiveness of shortening the day. The earlier varieties bloom under a longer day than the late ones.

With the varieties studied, a further decrease in the day length below 12 hours, even to 5 hours, had no greater effect as regards the time of blooming than the 12 hour day. However, the rate of growth was found to be directly proportional to the length-of-day.

From these experiments it became evident that a short day was necessary before soy beans and tobacco would bloom, and that certain varieties of the same species differed greatly as to just how short the days had to be before blooming would start.

Not content with being able merely to decrease the day-

length, Garner and Allard next attempted to increase the day-length by means of electric lights. At first they used intensely bright bulbs, but it was soon discovered that 40 watt bulbs provided enough light for the plants tested. In fact, it has since been fouud that as far as the length-of-day effect is concerned, artificial light 1/1000 the intensity of sunlight has the same effect. But a plant could not live under continuous light of such low intensity, as brighter light is required for food manufacture (photosynthesis). The low intensity lights used did not heat up the plants to any appreciable degree, the possibility of a temperature effect being thus eliminated.

It was found that short-day plants would not bloom when they were subjected to a day artificially lengthened by electric light. Bixoli soy beans grown in a lighted greenhouse made extensive vegetative growth but did not flower. Cosmos planted in an unlighted greenhouse November 1 bloomed by the latter part of December, but plants started at the same time and kept under a lengthened day until the long summer days arrived did not flower until the short days of autumn, when they were fifteen feet high.

Beggar-ticks, the common weed, did not bloom while added light was used, but it began to flower as soon as it was transferred to an unlighted greenhouse. Under normal winter day-lengths these plants bloomed when two inches high; under a lengthened day they grew all winter without flowering. Lima beans flowered and fruited promptly in an unlighted greenhouse, but the ones given added light remained sterile.

Plants normally blooming under the influence of long days acted in just the opposite way when the day was lengthened by means of electric light. Spinach planted November 1 and given added light was in bloom by December 15, while plants exposed to the normal day length did not bloom until late spring. *Iris florentia* normally flowers in May or June, and plants kept in an unlighted greenhouse bloomed at this time. However, grown under a lengthened day it bloomed in December.

By means of these and many other similar experiments Garner and Allard conclusively demonstrated that the time of blooming of most plants is controlled, not by temperature nor some mysterious inherent rhythm, but by the length of day, working in connection with the heredity of the plant, which determined just how the plant will respond to various day-lengths.

II. THE EFFECT OF LENGTH-OF-DAY ON FLOWERING AND FRUITING

Once worked out by Garner and Allard, the relationship between the length-of-day and flowering and fruiting seemed so simple and obvious yet so remarkable and significant that plant scientists all over the world began experimenting in this field. Some were still a bit dubious and wanted to check up on Garner and Allard's results, but always their findings were substantiated. Besides Garner and Allard, who continue to be the leaders in the field, the outstanding investigators have been Adams, a Canadian; Tincker, an Englishman; and Maximow, a Russian, although numerous American scientists have contributed greatly to the field. Altogether over one hundred scientific papers have been published on the subject, and research is still actively going on. It has been found that many other plant processes besides flowering and fruiting are controlled by length-of-day, but the most extensive experimentation has been done on this aspect, and it continues to be the most outstanding.

It has been found that plants may be divided into three groups on the basis of the time they flower: the long-day plants, which flower and fruit when the days are more than 12 hours long; the short-day plants, which bloom when the days are 12 hours or less in duration; and the everblooming or everbearing plants which in this latitude must be able to flower and fruit over a wide range of day-lengths. This classification is a bit arbitrary, however, as there is really a steady gradation from extremely long-day plants at one end, through everblooming plants, to the extremely short-day plants at the other end.

Long-day plants bloom in late spring and summer. Short-day plants bloom either in early spring or in autumn. In general, long-day plants will bloom if the light is extended to 18 hours or even 24 hours per day, while short-day plants will flower even if the light is reduced to six hours. But for some long-day plants the day may be made too long, and for some short-day plants too short. There is a certain length-of-day at which each species and variety will flower and fruit best.

An unfavorable day-length does not merely temporarily inhibit flowering, but is effective as long as it is allowed to operate. For example, Garner and Allard found that *Sedum spectabile* kept under 10 hour days from 1921 to 1929 did not flower at all, while the check plants exposed to normal daylight

flowered every year. In the spring of 1930 the 10-hour plants were put under normal daylight, and as the days grew longer they all bloomed.

A similar experiment was conducted with the radish, one of the outstanding long-day plants. A Scarlet Globe radish planted on May 25 began to bloom June 21. Then it was put under a 7 hour day. No seed was produced, the plant stopped blooming, and the vegetative growth was resumed. Through the fall and winter the plant was kept in a greenhouse and by spring the root had attained a diameter of five inches. As the longer days of late spring came around the radish finally bloomed, produced seed, and died. Thus an annual was changed into a biennial. It is probable that the radish could have been kept from blooming indefinitely had the 7 hour day been continued.

Spinach is another common long-day garden plant. If kept under an 8–10 hour day it will not seed and will produce excellent rosettes indefinitely. The same is true of lettuce.

Most farm crops, including corn, clover, the small grains, etc., are long-day plants. The fundamental distinction between the winter and spring types of wheat seems to be the rapidity with which the latter respond to the increasing length of day in spring. Wheat grows rapidly under long light; by using electric light to increase the day-length Harrington grew three generations of wheat in one year! The extremely long summer days in Alaska are largely responsible for the large crops of hay, wheat, potatoes, and vegetables grown there.

It is largely due to the longer days in the northern part of the central valley of California that oranges from there are ripe and ready for the market several weeks earlier than those grown 400 miles farther south.

Short-day plants bloom either in the early spring or fall. By far the greatest number bloom in the fall, apparently because in the spring the days become too long before the temperature has become high enough to permit the plants to resume activity. Short-day annuals are practically never ready to bloom in the spring, except in southern latitudes. In the case of most of our early spring flowering plants the buds have been formed the previous autumn and are ready to spring into activity the minute temperature and day-length are favorable.

Among the short-day plants which have been particularly studied, in addition to the tobacco and soy bean previously mentioned, are the wild aster, ragweed, dahlia, cosmos, poin-

settia, chrysanthemum, cypress vine, and nasturtium. All these plants have been made to flower several months earlier than normal by artificially reducing the length-of-day. On the other hand, they may be kept from blooming at the regular time by longer periods of illumination.

Poinsettias eight to ten inches high exposed to a ten-hour day after July 9 soon flowered and in 5–6 weeks the flower bracts (not petals) were a gorgeous red. Similar plants exposed to a 12 hour day bloomed by Sep. 3, but the bracts reddened very slowly. Check plants did not flower until November 12, while plants given added light did not flower at all.

Particularly extensive experiments have been performed on the cosmos. Cosmos planted November 1 and exposed to normal daylight flowered by December 22, when they were 30 inches high. Similar plants given artificial illumination up to midnight until summer and then exposed to normal daylight did not flower until the short days of October, when they were 15 feet high.

Another most remarkable fact was discovered through experiments on the cosmos. A plant was pruned so that it had more or less of a Y shape, the junction of the branches being close to the base. A light-proof partition was placed between the two branches, one being exposed to ordinary autumn day length, the other to added electric light until midnight. This branch continued its vegetative growth, not producing any flowers, while the one exposed to normally short days flowered and died. The basal portion continued to grow with the vegetative branch. Later experiments showed that by using horizontal partitions and light proof boxes the upper part of a plant could be caused to flower while the lower remained sterile, and vice versa. Moreover, the central portion of the plant could be caused to flower under short light while the top and bottom portions exposed to long light did not, or vice versa. However, it was found that if a part of a plant was kept continuously in the dark it responded in unison with the illuminated portion.

The violet seems to have been the most extensively studied of the spring-flowering short-day plants. A plant of *Viola fimbriatula* which had flowered normally in April was transplanted to boxes June 9 and exposed to sunlight only seven hours a day. By July it was again blooming, while check plants kept in normal daylight were producing only the inconspicuous closed flowers without petals (cleistogamous flowers) which

violets produce in the summer. By keeping the light at eight hours, violets have been caused to produce showy purple flowers continuously for several months, thus approaching a condition of everblooming.

We are accustomed to think of everblooming or everbearing plants as being particular species or varieties, as of roses or strawberries for example. However, many plants may be made into everbloomers by keeping the day-length within the range where both flowering and vegetative growth may take place. For Cosmos this is at about 12 hours, and for most plants the range is quite narrow, so we have few everbloomers in the temperate latitudes due to the constantly changing day-lengths. A few of our plants such as chickweed, dead-nettle, sunflower, dandelions, tomatoes, and certain varieties of strawberries, roses, etc., are everblooming over a wide range of day-lengths. Such plants are our only natural everbloomers. In the tropics, however, where the day-length is at or near 12 hours all the year around everbloomers are the rule and not the exception, just as would be expected.

III. OTHER EFFECTS OF LENGTH-OF-DAY ON PLANTS

The length-of-day controls, not only the time of flowering and fruiting, but also tuber, fleshy root, and bulb formation; stem growth; leaf fall and dormancy; senescence and rejuvenescence; sex expression; and indirectly, distribution of plants and crop producing centers.

In general, tubers and fleshy roots develop best under the influence of short days, while bulbs develop during long days. Garner and Allard found that a shortened day caused a pronounced increase in tuber formation in the yam, while the artichoke (*Helianthus tuberosus*) produced larger but less numerous tubers under these conditions. They also found that with fifteen or more hours of daylight Irish potatoes grew vegetatively; at thirteen hours they bloomed and produced some tubers; at ten hours tuber formation was abundant; while at five hours the plants resumed purely vegetative growth. McClelland ran experiments which also showed that a ten hour day was best for tuber formation in the potato, but that there is considerable difference in the sensitiveness of varieties to the length-of-day. Of the varieties he tested, Red Bliss was least sensitive and Lookout Mountain most sensitive, Irish Cobbler being intermediate.

Beet and radish roots grow best under short days, and McClelland found that Porto Rico and Key West sweet potatoes grew better at eleven than thirteen and a half hours. Zimmermann and Hitchcock found that dahlias produce fibrous roots under long days and heavy storage roots under short days. Carrots appear to be more or less of an exception, as a typical root will be produced under a 14 hour day and not under a shorter day.

Unlike roots and tubers, bulbs develop best under long days. At 10 hours Silverskin onion produced typical spring onions; at 13 hours a slight bulb was produced; while at 15 hours a typical large bulb was formed. McClelland secured similar results, finding that onions are very sensitive to length of day and that there is a great difference among different varieties. While all the varieties studied produced bulbs under a 15 hour day, Bermuda White seemed adapted to a maximum day length only shortly in excess of 13 hours, Silver King produced a few bulbs at 13 hours, while Prizetaker and Yellow Globe Danvers produced no bulbs at all at that day-length.

Comparatively long days also appear to favor maximum stem growth, at least in the case of short-day plants. Even some long-day plants will stop blooming and begin growing if the day-length is still further increased. Short-day plants kept under long days will grow indefinitely, giving rise to giant plants, while exposure to the shorter day favoring flowering produces dwarfs. Branching often takes place under a day-length favoring flowering, while there is little branching at the longer day lengths. Evening primrose rosettes placed under a ten hour day March 29 showed marked basal branching, while check plants did not branch. The two types of plants did not look as if they belonged to the same species. Weaver and Himmel found that typical long-day plants such as red clover, radish, oats, etc., developed large tops and extensive roots at 15 hours, and that the growth was reduced by shortening the day. Dahlia, ragweed, cosmos, and other short-day plants also attained the greatest size and root development at 15 hours.

On the other hand, when the day-length is reduced below that suitable for flowering many plants of both the long-day and short-day groups assume prostrate growth, with free stooling, rosette formation, etc. Thus it is primarily the short winter days rather than the low temperatures which induce winter rosette formation in plants such as the evening primrose, dan-

delion, and mullein, and which inhibit the growth of the grasses, winter wheat, clover, etc., during the winter. Short days also favor rosette formation in such long-day plants as lettuce and spinach.

While extremely short days thus favor rosette formation in some plants they have another effect on trees and shrubs. Garner and Allard found that in most cases leaf-fall and autumnal coloration of leaves are due, not to low temperatures and frosts, but to the increasingly short days of fall. This gradual transition from long to short days is necessary to induce leaf-fall; a sudden change from long to short days amazingly causes an evergreen response.

Extremely short days probably cause the death of short-day annuals; continued long days the death of long-day annuals (disregarding those killed by frost, of course). It appears that death follows seed production, perhaps because of the weakened condition of the plant. However, death would not occur even then if the day-length were only favorable. By restoring plants which have produced seeds and are ready to die to a favorable day-length they may be rejuvenated. Garner and Allard caused Bixoli soy bean to bloom as early as June 16 by exposure to short days. On June 20 the plants were restored to the normal day length. The seeds ripened, the leaves turned yellow, and the plants at first appeared to be dying. But then, under the influence of the long days, new shoots developed, the plants entered a second growth, and again flowered in September, the normal time. In a remarkable series of experiments Professor J. H. Schaffner of Ohio State University repeatedly rejuvenated hemp plants by exposing them to long light after they had started to die due to short-day influence.

Professor Schaffner also found that the sex of hemp and corn flowers can be controlled and reversed by changing the day-length. In corn, the female inflorescence (ear) develops under the influence of comparatively short days, the male inflorescence (tassel) under the influence of comparatively long days. By planting corn on November 1 Prof. Schaffner secured some degree of femaleness in the tassels of all the plants.

Another and rather indirect effect of length-of-day on plants is its partial control of the distribution of plants and crop-producing centers, as regards latitude. Such distribution has usually been attributed to differences in temperature and other

factors. While these are of course important, it now appears that many northern plants cannot become established in the tropics because the days there are never long enough to permit them to flower and produce seed, while many tropical plants cannot grow in temperate latitudes because the days of the growing season are so long that they prevent seed production.

The diversity and importance of the effects of day-length on plants suggest that it may have similar effects on animals. Although little experimentation has been done along this line, experiments on birds by Professor Baldwin and Dr. Kendeigh of Western Reserve University indicate that bird migrations are at least partially controlled by length of day. It seems at least possible that the periods of reproductive activity in animals, the hibernation of warm blooded animals, and similar seasonal activities are partially controlled by length of day, although this is pure speculation.

Whatever may be the case with animals, the widespread and remarkable influence of length-of-day on plants has been amply proved. Yet we must not jump at the conclusion that length-of-day is the only factor controlling and timing plant processes. Plants are complex organisms exposed to a complex environment, and no one factor naturally operates independently of the others. Such factors as temperature, water supply, etc., must always be favorable in order that length-of-day may operate as has been described. In some circumstances and with some plants temperature rather than length-of-day may even be the controlling factor. For example, Laurie and Poesch found that plants of *Lilium longiflorum giganteum* kept at 72° F. and normal daylight flowered by March 25; plants kept at 60° F and given six hours added light flowered by March 26; while check plants kept at 60° F and normal daylight did not bloom until April 10. In this case heat seemed to be as effective as length of day. H. C. Thompson of Cornell discovered that exposing young celery plants to low temperatures for 15 to 55 days induces flower and seed production the first year, while relatively high temperatures prevented seeding and favored vegetative growth regardless of previous treatment. There are a few other similar exceptions, but by and large temperature is not the controlling influence in determining the occurrence of seasonal periodicity. It has repeatedly shown that the controlling influence is length-of-day.

IV. PRACTICAL APPLICATIONS OF THE DISCOVERY

Despite the thoroughness with which the control of plant processes by length-of-day has been worked out, horticulturists and farmers seem to have been very slow in making practical use of this discovery. Numerous practical applications have been pointed out, and it is probable that others will be developed as time goes on.

For example, it will now be possible to determine the correct time to plant crops in order to secure the highest yields. A difference of two weeks or so in the planting dates may determine whether the plant activities will be largely vegetative or reproductive. This explains why some crops develop excessively large plants if put out too early.

The discovery has also been of great value to plant breeders. Previously it had often been desirable but impossible to cross two plants blooming at different times, but now it is a simple matter to make such plants bloom at the same time by properly regulating the day-length. Moreover, breeders now know definitely what to breed for when they want earlier or later varieties, more fruitful or larger growing forms, or improved everbearers. Similarly, plant introducers can save much time and work by selecting only species and varieties which will successfully reproduce under the day-lengths of the latitude to which the plant is to be taken.

In the case of leaf, stem, or root crops which are extremely productive in a certain latitude but will not seed there it is often possible to grow plants for seed in another latitude. This is being done with Maryland Mammoth tobacco. You will remember that in Maryland this variety produced three or four times as many leaves as similar varieties, but that it would not seed before frost. Now the seed is grown in Florida, where the days become short enough long before the plants are killed by frost, and shipped to the Maryland growers.

But the discovery is perhaps of greatest value to the florists, who can now force flowering at almost any time of the year simply by properly regulating the day-length. Prof. Alex Laurie and Mr. G. H. Poesch of Ohio State have conducted perhaps the most extensive experiments along this line, and in general their results have been most encouraging to the commercial grower.

They use two methods of controlling the length of day:

lengthening it by means of ordinary 100 watt electric lights, and shortening it by means of black cloth shades. Using cloth for shading was quite an innovation, as previously light-tight compartments had always been used to shorten the day. The black cloth allows a small quantity of light to filter through, but not enough to exert a photoperiodic effect. The cloth must be black; white or colored cloths admit too much light. The cost of the cloth is negligible, especially since it can be used year after year.

The principal short-day plants subjected to shading were the fall-blooming chrysanthemums, and the results were most satisfactory. Plants thus subjected to a short day bloomed 22 to 56 days earlier than those exposed to normal daylight, depending on the variety. The test flowers were every bit as large as the checks, while the flower stems were only slightly shorter. The effectiveness of the treatment depends upon the varieties, those responding the best being Celestra, Pink Chieftain, and Sunglow.

Such control is of immense value to florists. Good varieties can now be made to bloom at almost any time, so that inferior types which were used to secure continuity of bloom can now be discarded. More important, as far as the eastern growers are concerned, is the fact that they can now put choice blooms on the market to compete with the Western Coast flowers, which had formerly monopolized the early market.

The majority of the common greenhouse plants are long-day bloomers, and added light must be used to make them flower when desired. Laurie and Poesch found that many plants can be speeded up profitably if the cost of electricity does not exceed 3¢ per kilowatt hour. Thus, many plants may be forced into bloom during the short winter days. Herbaceous perennials such as Achillea, Coreopsis, Gaillardia, and Viola have been caused to bloom thirty to forty days earlier at little cost. Sweet peas flowered two to three weeks earlier and the midwinter drop was eliminated. China asters showed greater production and longer stems. Vaughan's Sunshine aster was forced to bloom by December 30, Centaurea on November 11, and Shirley Poppy October 22, while in each case the plants exposed to normal daylight did not bloom at all. Lilac Lavender stock was forced into bloom by January 14, while the check plants did not flower until February 12.

Gladioli did not respond well to additional light, nor did most

bulbous plants. However, Poet's narcissus flowered seven days earlier under artificial light, while Wedgewood iris produced 50% more bloom and longer flower stalks. With high temperatures, increased day-length produced earliness.

The cost of electricity used in bringing the plants into bloom several weeks or even months earlier than usual was surprisingly low. A large number of greenhouse species was forced to bloom from 25 to 75 days earlier at the infinitesimal cost of from 0.9 to 0.006 *of one cent* per flower. In a few cases the use of light was not economical, but with the overwhelming majority of species a great increase in earliness was secured at costs commercial producers could well afford.

NOTE: Readers who are interested in securing additional information on this subject are referred to Bulletin 512, Ohio Agricultural Experiment Station, Wooster, Ohio; October, 1932: *Photoperiodism: The Value of Supplementary Illumination and Reduction of Light on Flowering Plants in the Greenhouse*, by Alex Laurie and G. H. Poesch. This bulletin contains an almost complete list of the hundred or more scientific papers which have been published on this subject.

HYDROCYANIC ACID GENERATED BY MUSHROOMS

Hydrocyanic acid, deadliest of all simple chemical compounds, is formed in the caps of two species of mushroom, it has been discovered by M. Mirande, a French scientist. The poison was found in the gills of a small mushroom belonging to the genus Marasmius; it is extractable in cold water from both fresh and dried material, though neither the spores nor the underground root-like threads of the mushroom contain it.

The second hydrocyanic-acid yielding mushroom belongs to the genus Clitocybe; the poisonous night-shining American species known as the "jack-o'-lantern mushroom" is also a member of this group. This mushroom, unlike the Marasmius species, gives up its poison only when heated. —*Science Service.*

TYPESETTING MACHINE CAN NOW BE USED FOR SANSKRIT

Printing in Sanskrit, the ancient language of India, can now be composed on the Linotype machine. Hari G. Govil, a young Hindu scholar, has recently perfected the method with the collaboration of C. H. Griffith, of the Mergenthaler Linotype Co., the company has announced. The alphabet used for printing Sanskrit is called Devanagari, and though it consists of only 49 separate elements, nearly 700 separate characters are used, often consisting of two or three pieces of type one above the other. But by means of the Govil-Griffith system, this can now be set on the standard 90 key linotype. Devanagari is also used for Hindustani and a number of other vernaculars of India, and the new machine is expected to prove of value in modern India.—*Science Service.*

MATHEMATICS AND CIVILIZATION[1]

By G. A. Parkinson
University of Wisconsin Extension Division
Milwaukee, Wisconsin

"Die ganzen Zahlen hat Gott gemacht; alles anderes ist menschenwerk."[2] Kroneker.

Anyone who has studied the history of education in the United States has been impressed by the fact that periodically we engage in what might be called educational housecleanings. These so-called housecleanings manifest themselves in a close scrutiny of the curricula of our various educational institutions and very frequently in the radical modification of these curricula. I believe that these phenomena lend strength and vigor to our educational system in that they prevent stagnation and provide for that growth and change which are essential to any living organization. The only unfortunate aspect of these periodic changes is that very frequently they are instigated by laymen rather than by professional educators and these laymen are apt to have considered only a part of the educational and cultural picture and do not have an undistorted view of the whole problem. We realize how dangerous it would be for a surgeon who had studied only a portion of our anatomy to attempt to operate upon another portion of it, or even to attempt to work with that part which he had studied, if he did not understand its relationship to the whole body. It is equally dangerous for anyone to tamper with a part of the educational curriculum unless he has a keen appreciation of, and deep insight into, the interrelationships of the educational process as a whole.

At the present time there is a movement on foot in various parts of the United States, and in fact, in various parts of our own state, to re-organize the curricula of our public educational institutions. This is another one of the periodic housecleanings which have occurred so frequently, but in this particular instance the movement to which I refer is directed against the teaching of mathematics. At such a time as this it is important that we who are professionally engaged in mathematics should re-examine the content of our courses and the

[1] This paper was presented to the Mathematics Section of the Southern Wisconsin Teachers' Association at Madison on February 10, 1933.

[2] God made the integers; man has made everything else.

necessity for teaching these courses to our students. It is not that we must defend mathematics but that we should discover for ourselves anew the importance of this subject and should assist the layman, who feels that it is not important, to appreciate its unique position among the arts and sciences.

Let us begin our investigation in a truly mathematical fashion. We will start with several postulates or assumptions with which everyone will agree and then see if we can derive from these postulates certain conclusions which will show people not engaged in the study and teaching of mathematics the necessity for this subject. Let us assume first that education is desirable, that it is, in fact, an essential part of our civilization. I think we will have no difficulty in getting nearly every sane person to agree to this postulate. We must next agree upon what we consider the purpose of education. Let us say that the purpose of education is twofold: first, it is to prepare each individual as nearly as possible to take his place in and to enjoy the particular culture or civilization in which he finds himself. We are now speaking of education in general and are not restricting our remarks to any particular culture or country. The second function of education which is equally as important as the first is to prepare a few fortunate ones to advance the limits of knowledge and to assist in the development of their own culture.

We are now ready to proceed a little further in our argument. Since we have agreed upon the necessity for education and have agreed in general upon its objectives, we will all admit that it is necessary to teach something in our educational system. The question then arises, "What shall we teach and what emphasis shall be placed upon the various subjects which we do teach?" We have now passed the point where there can be unanimity of agreement and have entered the field of controversy. If we were to carry this question further in its most general form it would take us years to investigate all of its possible ramifications and the result would be a complete educational philosophy. While this might be desirable it is not the purpose of this paper. Our purpose now is to show the necessity for teaching at least one subject, namely, mathematics.

Since the avowed objective of our educational scheme is to help students to take their place in our particular civilization, the necessity for teaching mathematics is inherently connected with the importance of mathematics in our civilization. The

question is then: Is it necessary to teach mathematics, and if so, how much mathematics to students in order that they may all orient themselves in the modern world, that they may have a real appreciation of the culture in which they live, and that a few of them may help push the boundaries of that culture a little further ahead. Before discussing this larger problem I should like to digress just a moment and take up one point which is frequently introduced by those who wish to have mathematics as a required subject eliminated from our high school and college curricula, namely, that mathematics is too difficult for many students, that a large number of students fail the subject, and that the easiest and best way to eliminate these failures is to permit these students to study something else.

I feel that we have placed too much emphasis in our educational system on attempts to eliminate failures among students. I do not mean by this that we should be too severe in our courses or that we should deliberately plan to eliminate a large number of students, but I do mean that it appears to me undesirable from the standpoint of the students themselves to spend too much time and energy keeping them from failing subjects. Everyone meets situations in his life which he cannot conquer. The easier his path has been made for him in his younger years, the harder it is for him to attack difficult situations when he must rely exclusively upon his own initiative and ability. I believe that it is just as essential to teach students to react properly to failure as it is to teach them to acclimate themselves to success. It requires little training to teach a human to enjoy success but it requires a great deal of training and stiffening of the iron fibre of character to teach him to react properly to failure, and it is inevitable that each of us should experience some failure in his life. It is more important to teach a student to realize his own limitations than it is to make his path so easy that he never does learn the limit of his own capacities. In other words, I believe it is just as important for a student to experience difficulties in his education as it is for him to experience success and that the value of a subject in the school curriculum should be determined not upon the basis of its difficulty, but upon the basis of its value to the great majority of students who take it.

We are now ready to return to the question of the relationship between mathematics and civilization. I should like to discuss two aspects of this question. First, the relationship of mathematics to civilization in general, and second, the im-

portance of mathematics in this modern mechanistic civilization of which we are a part.

If we turn back the pages of history to the very earliest civilizations of which we have accurate knowledge, we find that there has grown up in connection with each particular civilization a particular system of mathematics as well as a particular system of art and music and architecture and philosophy. We will find if we continue our investigations in this field that there is a close connection between the mathematics and the other fundamental characteristics of the culture. In order that we may be a little more explicit as to just what we mean let us take for example a certain civilization and see if we can show this peculiar and close relationship.

Consider Greek civilization during the sixth century B.C. or about the time when the Pythagorean school of philosophy was flourishing. The Pythagoreans held, among other things, that the nature of all things lies in number. I wonder just what this means. The notion of number to these philosophers was a rather primitive one. A number was the measure of a space relationship, that is, to them it was the length of the edge of a block of stone or the circumference of a marble column, or in its most abstract mathematical sense the length of the side of a triangle. It had only to do with the relationship between the sizes of objects which were close at hand and which could be studied concretely. They had at this time no conception of space beyond that which was immediately observable or measurable. They had no conception of the notion of limit as we have in modern mathematics or of the notion of functional relationship. These concepts were entirely alien to their methods of thought and so the products of their mathematical genius were theorems regarding triangles, the sides of which represented for them the boundaries of space. We find these same ideas permeating their notions of astronomy. To them the universe was contained in the interior of a sphere of finite radius. The sky was a shell upon which were studded the stars like golden nails. We find these same general ideas permeating the work of their sculptors. They were not interested in showing character or development or change in their subjects for their whole object was to create in stone the essence of Being of their model in terms of size, symmetry, surfaces and the spatial relationships of the component parts. In the philosophy of these scholars we find again these same general methods of thought and the same general ideas.

Here we find no conception of the infinite and essentially no conception of change or functionality. To them a thing either existed or it did not exist. They had no notion of change or development and no conception of the flow of time. This is one of the reasons why they had no real history and had only myth and fable and tradition. We see from this very brief discussion that there was a close connection between the methods of thought in their mathematics and the methods which permeated their art and philosophy and history. To understand and appreciate this or any other civilization it is sufficient to understand and to appreciate, to its fullest extent, its mathematics.

This discussion may be continued almost indefinitely using various civilizations as examples. Since, however, we are especially interested in modern civilization and modern mathematics we shall now turn our attention to the work of Descartes, Fermat and Desargues in Europe during the latter part of the sixteenth and early part of the seventeenth centuries. Here we find an entirely new kind of mathematics coming to life. These mathematicians and their contemporaries had entirely divorced themselves from the Pythagorean idea of number. Number had ceased to be the measure of a concrete thing or space relationship but had become an entirely ideal concept. To them the line instead of being the edge of a block of granite had become a continuum of points. Curves, instead of being those mechanically generated curves of the Greeks, had become pictures of functional relationships between variables which extended beyond the visible and measurable portion of the plane to infinity. We find appearing at this same time the mathematical notion of a limit, a concept which in its modern sense was entirely foreign to classical thought and which is one of the most important foundation stones of modern mathematics. These same ideas which so clearly indicated the revolution which had taken place in mathematical thought were equally evident in the work of the philosophers such as Kant and Goethe. It appears that Goethe's abhorrence of mathematics was actually a revolt against the classical concepts of Greek mathematics and not an abhorrence of the mathematical spirit of his own time. When Kant tells us that, "Exact natural science reaches just as far as the possibilities of applied mathematics allow it to reach," he did not mean at all the same thing that the Pythagoreans meant when they stated that the nature of all things lay in numbers. This follows from the fact that for

Kant the notion of number had become infinitely more abstract and he had a mathematical picture of space which was entirely different from that of the Pythagoreans.

And now we find another important difference, between Greek culture and the modern western European culture of which we are a part, beginning to creep in. In the Greek civilization the philosophy and mathematics did not vitally affect the great mass of the people. Such things were the business of the scholars alone. But with the advent of the differential calculus of Newton and Leibnitz we find trends beginning to evidence themselves in this Western European culture which were to vitally affect people who did not realize that there were such things as philosophy and mathematics. We find at this time a new art developing, the art of transforming abstract mathematical concepts into machines of iron and steel which were revolutionizing the industrial and economic life of even the most unlearned and unschooled of the people. As a result of this it was gradually becoming necessary for anyone who wished to properly orient himself in this civilization to gain some conception of the ideas which were causing these economic and social changes. We can best obtain a picture of this situation by considering civilization in America today, for we have here the complete fruition of the new ideas and methods of thought which had their births in the minds of Descartes, Newton, Kant and Goethe. We find here in America an almost completely mechanized civilization. We find here a philosophy and a mathematic in which the fundamental ideas and their implications have been transformed into machines of steel and iron, in exactly the same way that the mathematical concepts of the Pythagoreans were molded into their columns and statues. From these things we see that a real understanding of modern civilization and a keen appreciation of its various fundamental aspects may be obtained through the study of modern mathematics. We are then ready to consider in some detail the contributions of mathematics to modern American culture. Let us consider a number of basic professions and see which of them require a knowledge of mathematics and just how much mathematics they do require. We will begin with the engineering profession. There are many different branches of engineering and many different activities within each branch. It is generally admitted that in all of these branches a knowledge of mathematics through the calculus is a prerequisite to the mastery of re-

quired courses. Many authorities go so far as to insist that mathematics through the calculus is not sufficient for engineers and insist that they shall have training in differential equations, harmonic analysis, vector analysis, and allied mathematical fields. We should remember in this connection that the branches of mathematics are developed in logical sequence and it is very frequently necessary to master a considerable amount of material which cannot be used directly in order to understand those theorems and results which have a practical application. In other words, the mastery of mathematics even through the calculus implies the necessity for thorough training in algebra and geometry and the proper place for a student to get this training is in the high school. Sometimes we find an engineer who claims that he does not use the calculus in his daily work, and yet even he will not recommend its elimination from the curriculum. The reason for this is that even though he may not use this knowledge directly, yet he must have the knowledge in order that he may read modern engineering literature intelligently and understand the new developments made by research workers in his own and allied fields. The very fact that the number of people engaged in engineering and allied technical activities constitutes an increasingly large percent of our population is a very strong argument for continuing to require training in mathematics in our secondary schools and universities.

There are many other professions and activities in which thorough training in higher mathematics is just as essential and just as useful as it is for engineers. In this connection may I quote f om the report of the committee on mathematics, Division of Chemical Education, of the American Chemical Society, presented at the Denver meeting, August 24, 1932. "The standard courses in mathematics through analytical geometry and differential and integral calculus are sufficient for the first course in physical chemistry. . . . For advanced courses in physical chemistry, and research in the newer fields of physical chemistry the mathematical training through calculus is insufficient." In physics and astronomy as well as in chemistry one cannot progress beyond the most elementary fields without training in mathematics which has carried him considerably beyond a first course in the calculus. In actuarial and statistical work one must have a knowledge of the theory of probability and the calculus of finite differences which require as a basis the infinitesimal calculus. We also have computors, research

workers, technical assistants and many other groups who must follow the golden path of mathematics at least this far. If one wishes to work in any of the applied sciences including education, psychology, botany, geology, zoology, economics or sociology, he must have a thorough training in mathematics, for we find that the methods of the differential and integral calculus are in the abstract the very methods which are used in all of these sciences. Even though one may not be planning to enter any of these fields of activity, he must have thorough training in mathematics if he is to understand and appreciate the work which others are doing in these fields. In other words, no individual can appreciate and understand even a small part of modern scientific and industrial activity without comprehensive training in advanced mathematics.

Many people contend that it is impossible to find out which high school students will go into scientific or technical work, and hence that it is unfair to compel all of them to take work in mathematics. It would appear that when a student is undecided as to the particular field of activity he will finally choose it is desirable to have him take those subjects which will open up for him the greatest number of possibilities later on and which will provide for him the most opportunities for the enjoyment of his leisure time in later life. Certainly there is no subject in the curricula of either the secondary schools or the universities which will provide a basis for understanding, appreciating and enjoying a larger number of human activities than the study of mathematics.

In addition to providing the direct attack upon the subjects which I have mentioned, mathematics teaches a student to concentrate on the analysis of any problem with which he may be engaged and helps him to gratify his desire for self-expression in the solution of problems. The technique which he develops in analyzing mathematical problems and deducing equations is the same technique that is required in every sort of precise reasoning. As a student advances in the study of mathematics he gains skill in the methods of reasoning and exact thinking and begins to gain an appreciation of the beauty of pure logic. These things are in themselves worth while even though they may not be used directly in the struggle for economic survival. He obtains here, training in effective expression and elegant simplicity of form and accuracy which cannot be obtained in any other way. There are few people who do not at some time

in their lives find it pleasant and profitable if they can express themselves with the clearness and simplicity of a mathematician.

In closing I should like to mention just one more reason for studying mathematics which seems to me to have been sadly neglected by the teachers in both the secondary schools and universities of our country, and that is that mathematics may become a really delightful hobby for those who have had sufficient training to really begin to appreciate its many subtilities. In continental Europe are found many clubs of amateur mathematicians and a number of periodicals devoted exclusively to the interests of these amateurs. I am sure that if the teachers in the United States would stress this particular reason for studying mathematics the number of amateur mathematicians in our country would increase enormously and we would have a larger, keener, and more widespread appreciation of the beauties of this science among the laymen.

POSITRON, ORESTRON, OR WHAT?

Just about a year ago Dr. Carl D. Anderson of the California Institute of Technology discovered a new unit of positive electricity but physicists have not yet agreed on what to call it. It appears to have the same electrical charge and mass as the electron, the unit of negative electricity, which has been known for many years.

Dr. Anderson has suggested that the new positive particle be called the "positron" and the old electron be rechristened to "negatron." This was to avoid confusion with the name "electron" that was originally devoid of significance regarding polarity.

Immediately many scientists objected to the rechristening and also to the disregard of mythology inherent in the word "positron." Prof. Herbert Dingle of Imperial College of Science and Technology in South Kensington, England, suggested the name "orestron" for the new positive particle. This is mythologically correct for Orestes was the brother of Electra.

The English physicists had in the meantime contributed to the confusion, but not in such a serious manner. The discovery of the positive particle had been made from an examination of curved tracks made by cosmic rays in plowing through a box filled with water vapor and placed between the poles of a magnet. Some of the tracks were bent in the wrong way. This could be explained only by having a new positive particle. But the sporting Englishmen immediately thought of cricket and the peculiar hops that the ball takes on bouncing in front of the wicket. These are called "googlies" so the new tracks and thus the particles became "googlies" also.—*Science Service.*

THE NATURE STUDY AND ELEMENTARY SCIENCE MOVEMENT

BY FLORENCE WELLER AND OTIS W. CALDWELL
Institute of School Experimentation Teachers College, Columbia University

We often think of the beginning of a movement as an entirely original program launched either because of some felt need, or in direct attack against current practices. Too often we neglect to recognize the gradual integration of ideas that leads toward the introduction of new types of subject matter or new methods of work. The elementary science movement is a case in point. It is proposed to present a statement regarding certain persons and movements that are important, though too often overlooked as factors, in the development of elementary science instruction.

The romantic Penikese School was conducted by Agassiz in the summer of 1873 in an old barn, on an uninhabited island, in Buzzards Bay, 18 miles from shore. To him came the leading younger scientific instructors of the country. David Starr Jordan says in his "Science Sketches' that it was, "the school of all schools in America which has had the greatest influence on American Scientific teaching."[1] Many of the students of this school became well known science instructors in Universities, but we are concerned here only with those who undertook to extend Agassiz's enthusiasm into the elementary school.

Henry H. Straight was probably the outstanding elementary science teacher of this group. He was born in Chatauqua County New York July 20, 1846. Being left an orphan while still a boy he supported himself working on farms. When sixteen, he taught his first school, and with the thirty-nine dollars received for the three months teaching, he entered the preparatory department of Oberlin College, Ohio. This amount with additional money earned—while studying, carried him through one year. During his junior and senior years he assisted in teaching the Latin and Greek classes in the preparatory school. His success in the languages led him to make philology a specialty, so at the end of his sophomore year he left college to earn money for study in Germany. During this period while principal of the public school at Galena, Ohio, he began a course of object lessons in science, and became filled with the idea that the natural

[1] Jordan, David S. Science Sketches. McClurg & Co. Chicago, 1886.

sciences are specially fitted to develop one's inherent capacities and to fit one for life. This idea was strengthened by study at Cornell University during his senior year, under Charles Fred Hartt, from whom he received an impulse second only to that which he later received from Agassiz. After his graduation he gave half a year to theological study and then left Oberlin to become principal of the State Normal School at Peru, Nebraska. A growing conviction of the value of science in public education, induced him to resign the position at the end of the year in order that he might take the more congenial situation of teacher of Natural Science and Psychology in the same school.

Here he laid the foundation of all his future work, mapped out a scheme of education based upon science and the industries, and in the winter of 1862, stated in his lecture entitled, "What We Want and How to Get It," the same beliefs and hopes that continued to find expression in his later teaching. A correspondence with Professor Shaler, in regard to a summer school of science for teachers, elicited much enthusiasm on his part, and when the proposed school was finally located at Penikese Island, his name was one of the very first on the list of prospective students. As a pupil of Agassiz he received the inspiration that was his guiding star. He became positive that laboratories can be so managed that large numbers may profitably experiment in them. He demonstrated this by converting the unfinished basement of the Nebraska Normal School into Laboratories. Much enthusiastic work was done here during the two years of his connection with this school.

In 1874 he was again at Penikese, the first part of the year of 1875 he spent with Professor Shaler and the State Geologist of North Carolina, in geological expeditions among the mountains of Kentucky, North Carolina, and Tennessee. The school year of 1875–76 was spent in special study at Cornell and Harvard, and in September 1876 he took the chair of Natural Science in the Oswego Normal School. He was then 32 years old.[2]

At Oswego he brought about a change from the study of separate lifeless objects to the study of living objects in their manifold relationships. "He saw that nature was a unity and that their was a vital relationship between all objects of study. Laboratory work was not adapted to childhood. The child wanted to study not the individual leaf but the whole tree

---

[2] Henry H. Straight. Historical Sketches. First Quarter Century State Normal and Training School. Oswego, N. Y. 1888 not quoted exactly, but slight changes made.

with the field around, or still better the forest. Mr. Straight led the children on field excursions and they investigated the woods, swamps, and lake shores with pencil or brush in hand."[3]

But the atmosphere at Oswego was one of severe logic, and while Straight had no psychological theories with which to defend his teaching, he intuitively felt that object teaching was false, that it was not in accord with life. He not only saw the limitations of the conventional object teaching, but the atmosphere in which it was taught irritated him and so, in 1883, when he was invited by Colonel Parker to the Cook County Normal School, he accepted.

Professor L. H. Bailey, in his "Nature Study Idea," said that Straight's views of science teaching in the elementary school underwent a gradual but decided change under the Pestalozzian influence in which he was placed. He saw the insufficiency of "object teaching" as an educational process. He sought to overcome these defects by "correlation of the subjects of study."[4]

Colonel Parker said in one of his lectures in his home geography series of the University of Chicago, that he desired to credit his idea of correlation to Straight, who was undoubtedly the first to correlate natural science with geography and other subjects in the curriculum.[5]

It would be difficult to interpret such statements so as to identify this kind of teaching with the tenets set down for nature-study in the Thirty First Yearbook of the National Society for the Study of Education. The committee writing that Yearbook present statements which are characteristic of only part of the nature-study movement. The following quotations are from the Thirty-First Yearbook:

1. Child psychology is distinct from the psychology of adults: this distinction justifies and requires a difference between nature study for elementary schools and science for high schools.
2. Nature study should be primarily observation of common natural objects and processes; the grouping of the facts learned in nature study to form principles and generalizations should be reserved for high school and college study.
3. A major value of nature study lies in the discipline which it gives in habits of thoughtful observation.[6]

Such claims as those made above are certainly not characteris-

[3] Mitchell, Dora Otis. "A History of Nature-Study" Nat. St. Rev. 19, '23, p. 296–7.

[4] Bailey, L. H. The Nature-Study Idea. Macmillan Co. 1911.

[5] Much of this information was obtained through an interview with Dr. Richard Piez of the Oswego State Normal and Training School.

[6] Thirty First Yearbook of the National Society for the Study of Education. Part I, 1931. Bloomington, Ill.

tic of *all* of the leaders of the period between 1870 and today.

Straight was the forerunner of Jackman of whom we speak later, Straight taught for the last few years of his life (1883–1886) at the Cook County Normal School under Colonel Parker. He died at the age of forty.

While Straight was initiating the elementary science movement at Oswego, Henry L. Clapp, Master of the George Putnam School in Boston, who had also been a student of Agassiz at Penikese Island helped to start the movement in Massachusetts.[7] But Arthur C. Boyden then an instructor in Natural Science in the Bridgewater State Normal School, and later its principal, did more toward carrying it out. "In 1889 a department of nature-study was established in the summer school at Cottage City. This was under the direction of Mr. Boyden until 1901. At first the work was called "elementary science"; but this seemed to be inappropriate, and "nature-study" was suggested. This term seemed to be a good equivalent of the German "naturkunde"—nature knowledge."[8]

Brief references are made to the work of Wilbur S. Jackman on pages 150 and 161 of the Thirty First Yearbook. Much more should be said in order to show Jackman's real contribution to the development of elementary science.

Among the graduates of the California, Pennsylvania State Normal School in 1877 was Wilbur S. Jackman, then 22 years old. He had lived on a farm about 2½ miles from town since he was 7 years old. As a boy he had "hitched up" a stream of water from the spring and made it run a wheel to churn the butter, thus relieving him of a particularly distasteful task. He knew and loved all of the birds and flowers in his small world. He planned and dug a pond on the front lawn and contrived to have a fountain work in it. He rode through rain, snow, heat, and cold on horse back to the State Normal School. He had little time for study and often said that most of his school preparation was done on horseback.[9]

Upon leaving the normal school Mr. Jackman became a successful science teacher. He was not like the teachers of today, supplied with elaborate material equipment in the way of laboratory layouts, apparatus, charts, and supplies, and with a background of objectified and statistically proved results of

[7] Boyden, Arthur C. "Nature Study Then and Now," Nat. St. Rev: 19, Mar. '23, p. 93.

[8] Bailey, L. H., op. cit.

[9] From correspondence with Mrs. Arthur Shillander, Mr. Jackman's daughter.

what to teach and how to teach it. Nor was Mr. Jackman's out-of-school environment like that of the present day teacher. In his time kerosene lamps were still commonly used; gas was just beginning to be piped to houses; the mazda lamp was unthought of. Those teachers who did not walk to school rode in horse cars. Cities were just beginning to be industrialized. His world was that of the period following the Civil War.

Mr. Jackman taught for three years. Then, realizing the need of a higher education, and perhaps desiring the cultural background that normal schools did not then furnish, he attended Allegheny College from 1880 to 1882 and then entered Harvard College from which he was graduated in 1884.[10]

"In 1884 Mr. Jackman began teaching biology in the Pittsburg High School. During five years' connections with that school he became strongly impressed with the necessity of having a broad foundation laid in the elementary grades for the study of science."[11] He had a large conception of the value of the study of nature. In one of his published articles he said that it meant giving the child new material and imagery with which the mind might grow. "Our schools," he said, "squeeze the life out of children. They take them eager, full of questions, they give them only symbols and abstract formal methods; they starve the minds and leave them poorer than when they came. The great variety which sky and earth, plant and animal, natural processes of change and movement afford, gives rich imagery and material, and suggests an expression in turn through a variety of means."[12] "The pupils were ignorant of the simplest phenomena that occurred about them. In the spring of 1889 he planned a general course in nature study and presented it to the superintendent and the principals of the ward schools in Pittsburg. It was agreed that in the fall he should have the privilege of meeting the teachers for the purpose of starting this work in the primary and grammar grades. Before the year closed, however, he received an invitation from Colonel Parker to enter the Cook County Normal School and take up the work with him. He entered on the work in the fall of 1889. During this year (1889) he elaborated the plan already begun. . . . . The features which perhaps most distinguished this scheme of nature-study were: (1) that it adopted the apparently

[10] Bigelow: "Wilbur Samuel Jackman," The Nature Study Review. Vol. 3, Mar. '07, p. 65–67.

[11] Bailey, L. H.: The Nature Study Idea. Macmillan Co., 1911.

[12] Tufts, J. H.: "The Significance of Mr. Jackman's Work." Elem. Sch. Teach. Vol. 7. Apr. '07, p. 443–446.

irregular plan of using all the material which the "Rolling Year," season by season, brought into the lives of the children; (2) that it rejected the idea of close and specialized study of inert or dead forms and sought to place the children in the fields and woods that they might study all nature at work; and (3) that, instead of looking upon nature-study as being supplementary to reading, writing, and other forms of expression, nature-study in itself became a demand that these subjects should be taught."[13] "He (Jackman) was an enthusiast but a quiet one, a great teacher."[14] It is significant that many people have made the following statement or a similar one concerning him, "To him more than to anyone else is due the position of nature-study in the elementary grades."[15]

Chief among his books is, "Nature Study For The Common Schools."[16] This appeared first in 1891 as bi-monthly pamphlets called "Outlines in Elementary Science," and was published as a book in 1894. In this book Jackman says, "Animal, plant, mineral, river, cloud, sunbeam, mountain, physical, and chemical changes are all matters of equal and absorbing interest to him (the child)." He gives this chart as a foundation of aims for the course.

Life & Its Phenomena	An Expression of	Energy acting through matter	Manifest in	Animal & Plant	The study comprehended in the subjects of	Zoology Botany Physics Chemistry Meteorology Astronomy Geology Geography Mineralogy

The aims or, motives, as he calls them are:

1. Introduction to and interpretation of the environment.
2. Inculcating truth and reduction of superstitious beliefs through the increase of the knowledge of truth.
3. Teaching the law of cause and effect.

This plan as sketched by Jackman does not compare unfavorably with our present day program. As developed, however, it outlines subject matter by months and by subjects in contrast to the large generalizations of science proposed in the Thirty-First Yearbook. When Henry Holt Co. asked for permission to

[13] Bailey, L. H.: op. cit.

[14] Bright, O. T.: "Wilbur S. Jackman," Elem. Sch. Teach. Vol. 7. Apr. '07, p. 433–438.

[15] Butler, Nathaniel: "Wilbur Samuel Jackman," Elem. Sch. Teach. Vol. 7, Apr. '07, p. 439.

[16] Jackman, W. S.: Nature Study For The Common Grades. Henry Holt & Co., 1894.

reprint Jackman's pamphlets in book form there was considerable correspondence concerning the title, the final result being the adoption of the name "Nature Study For The Common Schools." When a query was addressed to Jackman asking, "What is the relation of nature-study to elementary science?" he answered, "In the earlier days of nature-study in the elementary schools men of science were strenuous in their protest against calling either the subject or its method science. The objections urged may have been valid in some degree against the crude or rudimentary methods employed in the beginning, but they cannot be successfully maintained against the study when properly conducted. Nature-study, well planned, is scientific, and it differs not a whit in its essential from natural science. The obvious truth in this may be shown easily by a consideration of the matter and method in both."[17] There is a similar statement by Jackman in the Third Yearbook of the National Society for the Scientific Study of Education.[18] He goes on to compare the two, showing that in materials they are alike; that personal investigation and observation is necessary in both; that the use of the senses is of primary importance; and that both suggest law and order of the whole, thereby concluding that there is no natural dividing line between them.

In another small volume of Jackman's entitled, "Number Work in Nature Study"[19] he makes this statement: "The mathematics in connection with science work naturally divides itself into two parts. These are first that which pertains to the collection of accurate data, and second that which pertains to comparisons necessary in making generalizations." Again he remarks that, "it is perfectly possible so to frame a series of problems that each problem will lead a step nearer to that law." He has attempted in this book to give a list of questions requiring measurements or comparisons of nature materials.

Other publications include, "Field Work in Nature Study,"[20] a book useless for a person deficient in subject matter since it is formed almost entirely of questions; "Nature Study and Related Subjects,"[21] containing much subject matter again outlined by months; and "Nature Study for Grammar Grades,"[22]

[17] Jackman, W. S.: "Pedagogics of Nature Study," Course of Study. Vol. 1. No. 1.
[18] Jackman, W. S.: Third Yearbook of the National Society for the Scientific Study of Education. Nov. 1900, p. 195–196. Pt II. Univ. of Chicago Press, 1904.
[19] Jackman, W. S.: Number Work in Nature Study. Pub. by Author, 1893.
[20] Jackman, W. S.: Field Work in Nature Study. Pub. by Author, 1894.
[21] Jackman, W. S.: Nature Study and Related Work. Pub. by Author, 1896.
[22] Jackman, W. S.: Nature Study For Grammar Grades. 1899 Macmillan Co.

which is entirely content material under such headings as the following: Plants and Animals, Astronomy, Meteorology, Heat—Ventilation, Heat—Temperature, Heat—A Study of Energy, Heat and Energy in the Animal Body, Work and Energy—Machines, Equilibrium of Bodies—Center of Gravity, The Pendulum, Study of Stones, The Study of Wood, A Study of Light, Vibrations in Matter—Sound.

When Colonel Francis W. Parker accepted the presidency of the Chicago Institute, now the College of Education of the University of Chicago, he appointed Jackman to be associate professor with him. Jackman was Dean of the College of Education from 1901 to 1904 and then principal of the University Elementary School. The year previous to this he spent studying education in European schools particularly in England, Holland, France, and Germany. In these later years he also edited The Elementary School Teacher. James H. Tufts says, that there are three distinct movements in which Jackman was a leader during his short life time. First, by the introduction of the newest science teaching into high schools; second by the elaboration of the nature-study movement in the elementary grades; and third by bringing into mutual relation the work of the university with that of the training of teachers. He had much to do in bringing about the union of the School of Education with the University of Chicago. He died in 1907 at the age of 52 at the height of his service.

A third development which gave impetus to the nature-study movement was the enlarging of the Department of Agricultural Education at Cornell University (1893–1894). Let us place this movement historically with reference to the other sources. The famous Penikese Summer School was held in 1873. Straight and Clapp were students at Penikese and Straight taught until 1886. Jackman worked from 1877 to 1907. There was overlapping in time and undoubtedly in influence. Jackman attended Harvard and although this was after the death of Agassiz, he was undoubtedly influenced by Agassiz's students. Jackman followed Straight, 3 years after Straight's death, at the Cook County Normal School 1889. During this time Clapp and Boyden were teaching in Massachusetts, and only a few years previously the Cornell nature-study movement had been launched.

The Cornell movement was a direct outcome of the agricultural depression of 1891–93. In an effort to interest people to return to the country an appropriation of $8000 was given to

Cornell for the promotion of agriculture in New York State. A committee was formed headed by George T. Powell who decided that the first important step in helping agriculture was to interest children in the farm through nature-study.

In the words of Anna Botsford Comstock, "To say that the Professors in the College of Agriculture were filled with misgivings when they were bidden by the legislature to take this money and use it to teach nature-study in the rural schools would be putting it mildly; but they were good sports, and since it was their job they went at it earnestly though perhaps a little gingerly at first until sure of their ground. Then they forged ahead."[23]

The three outstanding leaders at Cornell were Liberty Hyde Bailey, Anna Botsford Comstock, and John L. Spencer. After the first year the development of the project was placed under Professor Bailey, who directed it for 15 years. His activities in this respect covered many fields. He wrote leaflets. He held summer schools in nature-study at Cornell (1899–1900). He established the Nature-Study Quarterly (1899). He lectured before many different kinds of audiences.

Professor Bailey was also the first president of the American Nature-Study Society. The first meeting which that organization held was at the University of Chicago, January 2, 1908. Professor Bailey was unable to be present and Professor Otis W. Caldwell was elected vice-chairman. By this time the movement had made definite headway. Many papers were read, the contents of which focused on whether or not nature study was a science. This was enthusiastically discussed. Finally W. E. Praeger, Professor of Biology in Kalamazoo, made an excellent summary when he said,

> In the papers we have just listened to there is one radical difference in the points of view. It has been stated with equal positiveness that nature-study is and is not a science. It is evident that the acceptance of one or the other of these statements may have far reaching influence on the content and method of teaching. I hold that nature-study is science and is simply the name applied to such parts of natural science that can appropriately be taught in the grades. The method of presentation of these facts will differ widely from that in use in the high school or college, but it is science teaching nevertheless.
>
> There should be no break in the continuity of science teaching from the kindergarten to college, no more than there should be in the teaching of literature or mathematics. The idea that nature is not science leads to serious results, the responsibility for accuracy seems to disappear, and

[23] Comstock, Anna Botsford.: "A Review of the Cornell Nature-Study Movement." Cornell Rural School Leaflet. Sept. '23, p. 41.

much of the nonsense and weak sentimentalism that has brought discredit on the subject is due to this fundamental error."[24]

Thus in 1908 Praeger undoubtedly voiced the thought of many, and later literature gives evidence that the two schools of thought remain separated, one going into sentimentalism and eventually dying out, the other surviving and being the foundation of our present elementary science. In a later edition of the Nature-Study Review we find this statement by Guyer:

> It would appear that at least two distinct ideas are masking under the name of nature-study. The first verges on the sentimental. Its aim is to waken in the child the proper emotional attitude toward nature. It has in mind the child's feelings and sympathies. The other regards more the child's intellect, the necessity of training him to observe accurately and to think clearly.[25]

Downing has evidently been aligned with the group that upheld nature-study as a training for the intellect for in 1907 we find this statement by him.

> Some unifying concept must be introduced or the course of study becomes fragmented, resulting in a series of uncoordinate efforts that lose their cumulative effect. In a course aiming to develop thought power this unifying factor would best be a series of logically related ideas or a dominant concept. . . . We must seek then some unifying idea in nature-study sufficiently complex to insure an increasing difficulty commensurate with the increasing power of the pupils.[26]

Downing then suggested the idea of evolution and presented selected matter to carry out the teaching of it. Undoubtedly this is a development of Jackman's idea concerning generalizations previously quoted from his "Number Work in Nature Study."

Another leader of the Cornell movement was Mr. John W Spencer, a fruit grower of Chatauqua County. He at first voluntarily helped the movement and then later as a member of the staff at Cornell became known to the thousands of Junior Naturalists that he had organized as "Uncle John." It was due to his efforts that Bailey, Cavanaugh, and Comstock wrote the first leaflets to help teachers.

Perhaps the most prominent teacher of children who was affiliated with the movement was Anna Botsford Comstock. Two striking sentences in the preface of her "Handbook of Nature Study" identify her genuinely and sincerely as a great teacher who spent all of her efforts on developing children rather

[24] Praeger, W. E.: Nat. St. Rev. 4. Feb. '08, p. 43.
[25] Guyer, M. F.: "Some Fundamental Needs in Nature Study," Nat. St. Rev. 4, Apr. '08, p. 111–119.
[26] Downing, E. R.: "Nature Study Course." Nat. St. Rev. 3. Oct. '07, p. 191–195.

than subjects of study. "It should be born in mind that if the author has not dipped deep in the wells of science, she has used only a child's cup" and "It should be stated that it is not because the author undervalues physics nature-study that it as been left out of these lessons, but because her own work has always been along biological lines."[27] There are others identified with the Cornell movement who need not be mentioned in this discussion of origins.

So the nature-study and elementary science movement has been one of steady progression. It has lived through a period when educators expounded extravagant aims for their pet hobbies, and it received a generous share of worthy criticism for proposing to cure school ills and to develop a perfect race. It has lived through the ample claims of its friends and severe criticisms of its opponents. It is today still so challenging that in a questionnaire sent to principals throughout the country 128 out of 172 declared that there is a decided increase of interest in nature study and elementary science. Examination of courses of study show a steady increase of use, but more important still, steady increase in clarity of results to be derived from nature study and elementary science.

[27] Comstock, Anna Botsford: Handbook of Nature Study. Comstock Pub. Co., 1911.

HEARING THROUGH HEAD BONES AIM OF NEW AID FOR DEAF

A small-sized portable device that enables deaf persons to hear through bones of the head has been developed by Dr. Hugo Lieber of New York.

The method of hearing employed, which is known as bone conduction, dispenses with the outer and middle ear as channels of sound, and instead carries vibrations of sound to the inner ear by way of teeth or head bones. The deaf composer Beethoven used the well-known principle when he placed a flat stick between his teeth and rested the tip of the stick on the piano in order to catch some sounds of his own music.

Efforts to produce a small device using this principle have met with the obstacle that small vibrators would "freeze" if sufficient power needed for hearing was transferred to them. Dr. Lieber's invention, he claims, has overcome this difficulty.

In the new oscillator, power has been increased and the converted sound vibrations are conveyed to the bones of the head by the housing of the oscillator instead of by a small disk.

"In this new vibrator," Dr. Lieber explained, "a small gap enabling the production of large power is obtained by using a rigid diaphragm stiff enough to vibrate and yet prevent the freezing action. By its construction it enables transmission of the vibrations over the casing which encloses the oscillator."

The device is being placed on the market by a company with which Dr. Lieber is connected.—*Science Service.*

PUPIL GROUPING IN PHYSICS TO APPROXIMATE INDIVIDUALIZATION

BY MAE ELIZABETH HARVESON
Frankford High School, Philadelphia, Pennsylvania

The Problem. The teacher of physics, until recent years, occupied an enviable position. His classes were relatively small and his pupils highly selected. The fact that his subject was the last in the science sequence meant that his pupils were usually seniors, with a background of three years of science work and, more often than not, as many years of mathematics. He could comfortably devote his attention to the teaching of his subject, for, with such an audience, the more important task of teaching his pupils, was accomplished as an almost invariable by-product.

Today the story is somewhat different. The limitation of the number of subjects a pupil may carry has made it less usual than formerly to find pupils in the physics classes with a complete background of mathematics even if the preceding science subjects have all been studied. This and the making of physics an elective subject in either the third or the fourth year, have been largely responsible for the fact that the population in the physics classes, though not so heterogeneous as that of the modern school as a whole, is decidedly more cosmopolitan than ever before.

Obviously the needs of these pupils with their varying educational backgrounds, native abilities, interests and plans for the future cannot be met with a single, highly-mathematical, college-imposed course in physics.

Even before the pupil differences became as marked as they now are, the writer was disturbed by the growing conviction that physics as it is usually taught in our high schools, makes little contribution to a pupil's understanding of the increasing number of intrinsically interesting developments and devices in his physical environment. A physics course which requires nearly half the time to be spent in the solution of problems which only experts in restricted fields will ever *use* in their vocations, or which a few pupils may need in order to pass college or scholarship examinations, is not the course to prepare all boys and girls to live in and enjoy to the greatest possible extent, a physical world.

Admittedly, those pupils who need the mathematical physics

must have it. It seems equally just and proper, however, that those pupils who do not need this type of course, and who are not fitted by interest, preparation or ability to profit by it, should be given a more popular, less mathematical or even non-mathematical course. This latter idea is often opposed by some teachers of the older school, on the ground that physics, shorn of its mathematics, has lost its identity. This point of view the writer cannot share.

Since the difficulty of arranging for these two types of work in separate classes seems practically insurmountable in a large, overcrowded, public high school, the less desirable, but next best plan is to vary the course within the limits of the class. This plan has been followed for two terms in the Physics I classes at the Frankford High School and, during the current term, has been extended to the Physics II classes.

The Plan. The pupils entering the Physics I classes are asked to record their mathematical and science high school history This includes the courses taken and the marks received. They are then asked to state their object in taking the course, that is, preparation for college, nursing, or some other post-high school activity, or meeting the year's requirement in science for graduation, or acquiring senior credits, etc. They are then given the Iowa Placement Examinations in Physics Aptitude. After a consideration of each pupil's educational history, future plans, aptitude and wishes in the matter, he is advised to take a mathematical or a non-mathematical course in physics, as the case may be. This placement of the pupil is never an arbitrary decision on the part of the teacher. The pupil may do as he wishes after the teacher's advice is given.

The mathematical course is the usual course in physics. The non-mathematical course eliminates practically all problems. It substitutes for these, research work along topical lines. These topics are not original with the writer, but have been gleaned from several text-books and they include biographies, histories of modern appliances, special applications of physical principles and other angles of the physics work. This term, forty topics are listed in Physics I, of which each pupil must report on fifteen. This number seems to allow sufficient choice to satisfy a variety of interests.

The research work on these topics is done partly in and partly outside of class. One day of each week is set aside for special work and on this day the pupils in the non-mathematical course

may consult any of the references available in the room, while the other pupils in the class solve problems under the teacher's direction. Any additional search for material must be made outside of class, but the time required for this ought not to exceed that spent by the other pupils in the preparation of their problems.

The reports on the topics studied are written. There is no prescribed length for each paper, but each discussion must be based on at least three references,—the names of these references, with exact pages, to accompany each report. An outline of the topic must also be included. Sample reports are displayed on the bulletin board at the beginning of the term to enable the pupils to understand the standard of work required.

Whenever time permits, the best reports on those topics of greatest interest to all the pupils, are read in class. Unfortunately, not nearly as much of this can be done as one would like.

In Physics II, the plan is modified. Here the amount of time normally spent in problem work is less than in the preceding course, consequently there is more time available for reports of the special studies. This term, there were forty-eight topics suggested for special study, of which each pupil must select at least one. The character of many of these topics is different from that of the Physics I topics. Here one finds such subjects as television, the cosmic ray, atomic structure, atomic disintegration, colored movies, sound pictures, Thomas Edison, Einstein, etc. The pupil's aim is now stated as the collection of *all* material he is able to find on the subject he has selected. He must consult books and periodicals,—in some cases the latter sources being the only ones available. His report is now delivered orally, with the aid of blackboard diagrams and any other illustrative material he is able to procure.

In the laboratory work, there is no distinction made in the requirements for the two courses. Some arithmetical processes must necessarily accompany certain of the experiments, but these are never very elaborate. Moreover, with the exception of possibly three experiments, all the laboratory work is carried on in groups. The results of the experiments are worked out as a group project. In some cases, where the group comprises five or six pupils, a record-keeper is chosen to record the data,—frequently on the blackboard,—and the calculations are checked by the group members. Thus even pupils in the non-mathe-

matical course have some contact with the mathematical side of the work.

One of the problems facing the teacher who tries to offer two different courses simultaneously, is the matter of flexibility. A pupil should be able to change from one course to the other with a minimum of friction. The writer's experience has been that the only changes likely to be made after the term has begun are shifts from the mathematical to the non-mathematical course. These will occur in the cases of those pupils who decide, after a week or two of the problem work, that they find it too difficult. A certain amount of the report work is required to be made up by these pupils.

The question of marks for the two types of work in physics is an important one where these artificial criteria still have so much weight. In our case, we put on the permanent record card of those pupils taking the non-mathematical course an explanatory note containing the information that the work in physics is not to be used for college entrance credit.

Results. While a year is scarcely a sufficiently long time in which to reach conclusive results on any experiment in pupil grouping, tendencies and trends may be recognized and tentative conclusions made.

If one is looking for objective evidence of the success of the plan as evinced in a higher percentage of pupils making a passing grade, he may not find it. The failures, however, are rarely in the non-mathematical course and, when they do occur there, are due to long absence or to that total lack of application which one occasionally finds in a pupil even as far advanced as the fourth year. The failures are practically limited to pupils who are taking the mathematical course, contrary to the dictates of all the evidence from past work and from tested aptitude. Sometimes parental pressure is responsible for the course chosen; sometimes a false notion of the prestige to be derived from the harder course.

Looking at the working of the plan from the inside, the teacher seems to see a better adjustment of work to pupil ability. The pupils in the non-mathematical course appear to show less of the strain and worry that marked the vain struggles of those of similar tastes and ability in the days when they had to attempt the mathematics. The pupils in the mathematical course derive considerable satisfaction from their ability to solve the problems and work diligently on this phase of the

work so that they may cover as much ground as possible. Some of the pieces of research done by the pupils on their topics have been very good and frequently the most excellent products have come from just the pupils who would have failed most miserably in their problem solutions. We have thus substituted for failure with its unhappy psychological effects, the satisfaction of a worthy task well done.

The writer feels that the experiment has justified itself and is well worth continuing.

ULTRAVIOLET LIGHT IN INDUSTRY

There is no question about the value of ultraviolet light in producing the anti-rachitic vitamin D, but this application is gradually giving way in importance to other applications of the invisible light. New applications are being made with such rapidity that no one can hope to predict what product will be subjected to ultraviolet treatment next.

Like most new applications of science to industry it is being used to prey upon the credulity of the uninformed purchaser, and he has been persuaded to pay a premium for irradiated goods that are not improved and perhaps partially spoiled by the treatment. It is such a practise that has given the ultraviolet treatment a black eye and has caused many people to shy away from it and not take advantage of the many real advantages that it possesses.

Ultraviolet light is now being used extensively to test the deterioration of substances exposed to sunlight. Since ultraviolet sources can be made much more intense than sunlight it is possible to test paints, varnishes, papers, dyes, rubbers, and glasses by very short exposures to this artificial sunlight. Other products that have been tested for spoiling on the exposure to light are gasolines, foods and tar products.

It is now definitely established that dairy cows properly treated with ultraviolet radiation produce milk rich in vitamin D. The radiation is absorbed through the thin skin on the under side of the cow. Agricultural experimental stations are growing crops in the winter in ultraviolet illuminated greenhouses. Seeds that would not otherwise germinate are changed so that a larger percentage will grow.

The use of artificial sunlight in the preparation of various kinds of food is gaining in popularity. Such short wave-lengths as are in ultraviolet radiation will kill many kinds of bacteria particularly if it is applied in large doses. The dehydrating industry that dries fruits which keep without the addition of preservatives have found that irradiation with artificial sunlight is a surer method than exposure to sunlight. Bread that has been treated after wrapping in a transparent paper will keep for at least ten days without molding. This is especially valuable with low carbohydrate breads such as are used by diabetics, for a central bakery can supply this special product to a wider region without spoilage.

Laundries have recently adapted the practise of bleaching by use of sunshine lamps. Many chemical processes that depend upon light are now substituting ultraviolet lamps for sunlight. Legal authorities have seized upon it as one of the surest methods of detecting forgeries and counterfeits. As many engineers have said, there is every reason to believe that the next few years will witness a many-fold increase in the application of radiant energy to the needs of the industrial world.—*Science Service.*

TEACHING HIGHWAY SAFETY THROUGH HIGH SCHOOL SCIENCES

By Dr. Herbert J. Stack
Columbia University, New York

Recent studies of motor vehicle accidents covering over one million drivers have revealed the fact that the accident rate for the High School motorist is nearly twice that for the adult over forty years of age. This seems surprising and is convincing that more must be done by the high schools of the Country to teach highway safety. We see that the economic loss from motor accidents last year exceeds two billion dollars, even greater than the total cost of public education. We are told that we probably paid more for crashes last year than we paid for new cars. These are striking and challenging facts for our new education to consider.

We have always felt that much more could be done in the high school sciences than is being done to teach highway safety. This does not mean actually giving students road instruction and tests to students but rather the laying of a foundation of the safety subject matter involved.

There are several of the sciences that may make a distinct contribution to safety. Physics and General Science are the most important. Let us see what might be included in the subject matter in these two subjects that would contribute helpful information.

PHYSICS

Mechanics:

Discussion and problems having to do with the speed and momentum of automobiles for example:

1. An automobile weighing 3000 pounds is moving at the rate of 60 miles per hour. What momentum does it have? This would be equivalent to falling freely from what height?

2. An automobile traveling thirty miles per hour requires 40 feet to come to a full stop after the brakes are applied. How many feet will be required to bring the car to a stop when the speed is doubled?

3. An automobile is moving at the rate of 50 miles per hour. Under ordinary conditions with four wheel brakes the motorist should be able to stop in 109 feet after the brakes are applied. But the reaction time of the motorist is :5 second. What will be the total distance required to come to a full stop?

Problems under Friction:

What kinds of road surfaces give the smallest coefficient of friction?

What are the effects of various types of tires on friction?

What kinds of braking systems are used on motor vehicles?

What is the effect of poorly adjusted brakes when stopping a car?

What methods are used in testing brakes in good brake testing stations?

What is the effect of using tire chains under various surface conditions of roadways?

What are the best methods of bringing a car to a stop that has started skidding going down a slippery hill?

What are the best methods of getting a car started when it is stuck in mud or snow?

Under Centrifugal Force:

What is the effect and danger of rounding curves at high speed?

What is the reason for elevating the outside of a curve on a highway?

Under Machines:

What are the dangers associated with a slipping clutch?

What dangers may arise when using certain kinds of free wheeling?

How can we find out if a car has defective steering mechanism?

Upon what principles do automatic windshield wipers operate?

Under Light:

Explain the construction of the automobile headlight. What should be the characteristics of a safe headlight?

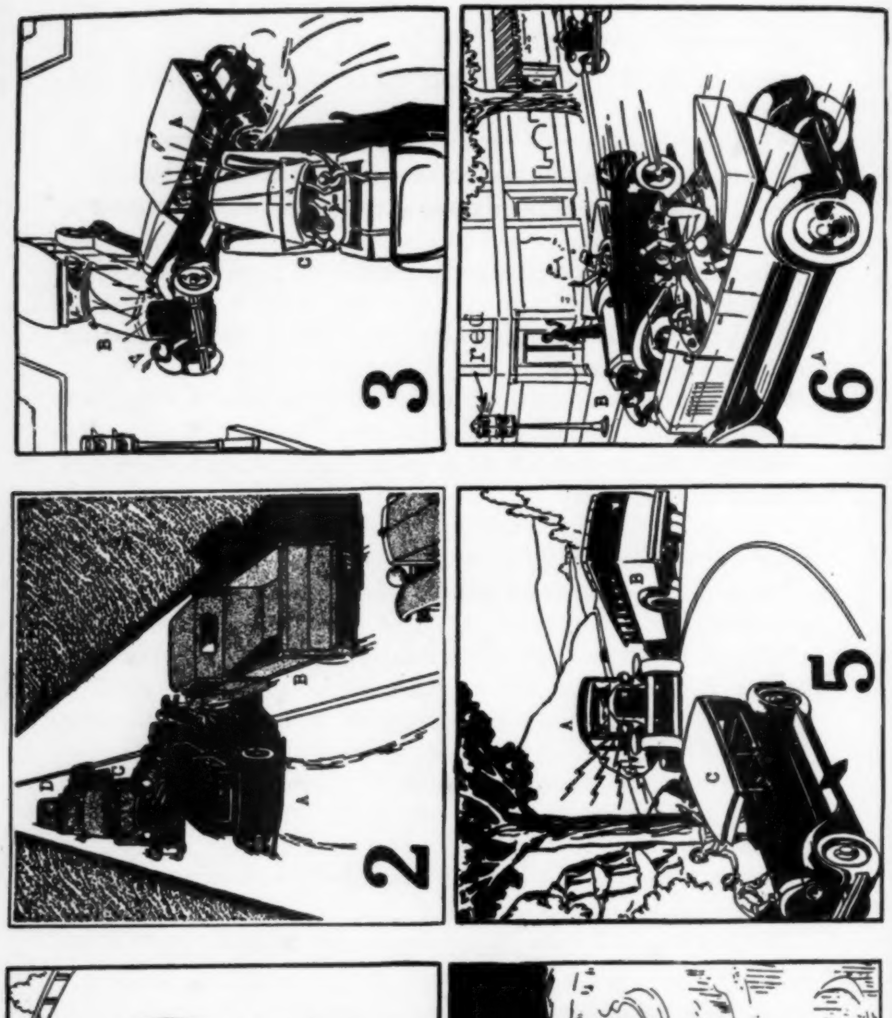
What principle is used in the deflecting beam used in most headlights?

What is the best kind of lights to use in a heavy fog?

What are the lighting systems used for traffic control?

What is the principle used in the red reflecting lens used on highways and also on the back of motor vehicles?

These are samples of a few of the problems that might be discussed in the class in physics.


1
2
3
4
5
6

In connection with the material suggested in the outlines above it is suggested that teachers of physics and general science use tests such as the one included in this article.

SAFETY TESTS

How many violations of safety rules can you find in the pictures shown above? What are they?

What physical laws have been disregarded in each case?

Which cars are at fault in each violation?

GENERAL SCIENCE

The problems of safety come up often in general science. In fact an analysis of textbooks and courses of study show that this subject contains the most references to safety of any of the secondary school sciences including fire prevention, dangers of poisonous substances, first aid, drowning, firearms, explosions, machines and highway safety. In the outline that follows we are only including some of the items that might be included under highway safety.

In the Unit on Transportation:

How automobile accidents are caused and how they may be prevented.

How defective conditions of cars contribute to accidents.

The automobile drivers test—what it should include.

Safety devices on automobiles.

In the Unit on Safety:

How pedestrian accidents are caused.

Safety in driving a car.

The dangers of railroad highway grade crossing accidents.

Other dangers on the streets.

How the community controls traffic.

In the Unit of Lighting:

The importance of street lighting in crime prevention and accident prevention.

Best types of automobile headlights.

The value of bicycle lights and reflecting lenses.

In conclusion, teachers of sciences in the High Schools will naturally ask the question "Why should we lay this special emphasis on safety and accident prevention? This is just one phase of the subject matter with which we are dealing." Our answer is based upon the mortality statistics and accident records of the High School youth of the country. Last year over 2500 persons of high school age were killed and over 70,000 injured in automobile accidents. Knowledge regarding some of the subject matter that has been suggested in this article might have prevented some of these accidents. Moreover, nearly 4000 more persons of high school age were killed and 200,000 injured in other kinds of accidents.

The schools have a real responsibility to do what they can through various subjects to prevent these accidents that not only cause a severe loss of life, but also untold suffering and economic distress.

THE NEW ADVANCE IN ASTRONOMY

By Wm. T. Skilling*
State Teacher's College, San Diego, California

An infant will reach for the moon, they say, but finding his arm too short will devote his attention to nearer toys. But astronomers, since Hipparchus, have reached, not only for the moon, but for objects as far beyond it as the moon is beyond the child's toys, and have, in a measure, grasped them.

Advances that astronomy has made in recent years into the unknown can only be compared with the sudden leap forward which the science took when Galileo, in 1609, first turned his little telescope onto the heavens.

As in Galileo's time, the progress now is due, largely, to new inventions, but not wholly so, for there are places to which optical instruments, powerful as they are, will not penetrate. One of these places is the center of the sun. To reach such a place requires, as Eddington puts it, an "analytical boring machine."

Too many people picture an astronomer as a gray bearded philosopher who sits all night with his eye at the end of a telescope, gazing up into the starry heavens. It would astonish such people to visit an actual observatory and find a group of men who might well pass for any sort of business or professional people, working by day in laboratories and offices, and by night, not looking at the sky but photographing it.

The telescope nowadays, though as important as ever, is not an end in itself, but is simply a light gathering device, at the focus of which are placed such instruments as the camera, the thermocouple, the radiometer, the spectrograph, the spectro heliograph, or the interferometer. With such instruments, and many others to be seen in the astronomers' laboratories, an interpretation can be given of the radiant energy sent from the sky, vastly transcending any interpretation which could result from mere visual observation through even the most powerful telescope.

Astrophysics is the newest and most interesting field of astronomical research. And since the sun is our nearest star, astrophysics begins with a study of the sun. Most of the in-

* The Author of this article will be well remembered for his excellent series of articles on "Background and Foreground of General Science" published in Volumes 29, 30 and 31 of this journal. During the summer Professor Skilling brought out a new text in general science entitled "Tours Through the World of Science" published by McGraw-Hill—Ed.

struments mentioned above, and others as well, are used for analyzing solar radiation. Dr. Charles Abbot, director of the Smithsonian Institution, has established laboratories in various parts of the world, in mountains, lowlands, and deserts, to determine the total amount of heat coming from the sun. He calls his heat measuring device a pyrheliometer, and with it he finds that 1.94 calories per minute would fall upon a square centimeter held perpendicular to the rays of the sun in any part of the world, at any season, *if it were not for the earth's atmosphere.* The air under most favorable conditions, that is, at the equator at noon, absorbs about 30 per cent of this heat, and lets the rest pass through to the ground.

The work on the sun that Professor Rowland of Johns Hopkins did thirty-five years ago with the spectroscope, has recently been carried further toward completion. Rowland found lines in the sun's spectrum which he attributed to thirty-five different elements. Today no less than sixty-one of Earth's ninety-two elements have been discovered in the sun.

Not only does the spectroscope reveal the elements floating in gaseous form in the sun's atmosphere, but it shows in what form these elements exist. Some of them in the coolest part of sunspots are in the form of certain very refractory compounds. Some atoms outside of spots, are in their normal state, at a low level of energy. Some are excited to higher energy levels. Some are even singly or doubly ionized, that is, they have had one or more of their electrons driven away by the fierce turmoil in which they reside.

All of these deductions are to be drawn from a study of the lines in the sun's spectrum. They are made possible by a comparison of the sun's spectrum with those of known elements in the physics laboratory vaporized at the various temperatures which an electric furnace, an electric arc, or an electric spark will supply.

There is now being constructed at the California Institute of Technology a solar furnace, consisting in part of nineteen two foot lenses, which will all focus the sun's rays on the same spot, having an area about the size of one's little finger nail. This burning glass will create a temperature of probably 4500 degrees centigrade, sufficient to vaporize any known substance. Light from these vapors will be studied with the spectroscope.

One of the most powerful means astronomers have of analyzing sunlight was invented, in his student days, by Dr. George

Ellery Hale, who has since been so influential in shaping the policies of two great observatories, Yerkes and Mt. Wilson. His spectroheliograph photographs the sun in the light of *one* element. The instrument is like a spectrograph except that it has two slits, the second one being placed on a given line of the spectrum. The first slit is moved over the image of the sun, and the second slit is, at an equal rate, moved over a photographic plate.

The "tower telescope" has greatly assisted solar study, which requires high magnification, but does not need great light gathering lenses. Magnification depends on the *length* of the telescope. A tower may be built to almost any height, but a very long telescope pointing at an angle would bend of its own weight. A mirror run by clock work throws sunlight straight down through the tower. The 150 foot tower telescope at Mt. Wilson gives an image of the sun for study 17 inches in diameter.

Sun spots, always interesting, and possibly sometime to be of practical importance to the weather bureau, have yielded many of their secrets to the battery of observing instruments that have been turned upon them. First, the thermocouple and the bolometer have fixed their temperature at about 4000°C., two thousand degrees lower than that of the rest of the surface of the sun. This temperature difference is greater than the difference between the inside of a refrigerator and the inside of a stove.

Next, magnetic instruments have shown the spots to be strong magnetic fields. Finally, the causes of the comparative coolness and of the magnetic field have been made clear by the spectroscope and the spectroheliograph. The Doppler effect, made evident by the spectroscope shows that the gases after rising up out of the body of the sun spread out rapidly in all directions along the surface. This causes rarefication and consequent cooling. The spectrohieliograph shows a whirling motion around the spot which should be sufficient to produce a magnetic field since the gases are highly ionized.

In order to make knowledge of the sun useful in interpreting the stars it is necessary first to prove that the stars are indeed like the sun. The spectroscope makes this proof conclusive. Some stars have a spectrum practically identical with that of the sun; the same elements, the same temperature, the same degree of ionization of the elements. Moreover the interferometer measures the size of the stars. Though capable, so far, of measur-

ing only the larger stars, vastly superior to our sun, it paves the way to a classification of all stars, in which the sun appears as a star of rather less than average size and brilliance.

New methods of obtaining distances to the stars have been discovered greatly extending the range to which measurements may be made. Since the nearest star is 272,000 times as far away as the sun and since the stars (except double ones) are spaced at distances approximately as great as our distance from the nearest, it is easy to see how difficult becomes the ordinary surveyors' method of finding parallax.

Two indirect methods of measurement are especially remarkable, one due to Dr. Adams, director of Mt. Wilson observatory, the other to Dr. Shapley, director of the Harvard Observatory. Both these methods of finding distance find *first* the actual brightness of the star, and from that distance is easily deduced.

The Mt. Wilson method employs a spectrum of the star. Large stars of a certain color give a spectrum differing in certain lines from the spectra of smaller stars of the same color. The amount of this difference in spectra indicates the amount of difference in size, therefore in brightness.

The Harvard method is applicable only to certain stars called "Cepheid Variables." The period of their variability depends on their size and so on their brightness. The actual brightness is therefore to be gotten simply by observing the time it takes the star to brighten up and dim down again.

Having obtained the actual brightness of a star by any method it is a simple matter to get its distance by comparing its *apparent* brightness with the apparent brightness of some nearer star of *known* actual brightness.

The Cepheid variable method of determining star distances has enabled astronomers to measure not only to the limits of our stellar system, whose diameter is now placed at about two hundred thousand light years, but to probe on out through empty space beyond our galaxy until the "island universes" millions of light years away are reached. These are the so called "spiral nebulae," many of them showing spiral form.

The similarity of the spiral nebulae to our own stellar system is suggested by the fact that their spectra are just what would be expected of a spectrum of our galaxy taken from far beyond the Milky Way.

A more conclusive proof of the nature of the spiral nebulae

is that our most powerful telescopes are able to resolve the nebulous mass into distinct stars.

Some of these galaxies are so far distant that the light by which we see them started on its journey to us before man came upon the earth. It is around them that much of the keenest interest among astronomers centers.

Most remarkable in the behavior of the spirals is their apparent rapid motion from us. Those at greater distances appear to move faster than nearer ones, until at a distance estimated to be 100,000,000 light years their velocity of recession is 12,000 miles a second.

The Doppler effect, which causes lines of the spectrum to shift toward the red is used as a measure of the velocity of the nebulae.

Someone has disposed of the question as to why the spirals are all retreating from us so fast by the remark, "Do you wonder?" But Einstein, and others, more serious, are trying to connect the phenomenon with the theory of relativity.

Perhaps the anticipated 200 inch telescope will help us to solve some of our waiting problems. When we consider that its concave mirror will be as large as the floor of a room seventeen feet square we get some idea of the tremendous amount of light it will gather from dim and distant stars, in comparison with the amount of light that can enter the unaided eye whose pupil is about one-fifth of an inch in diameter.

MEETING OF SCIENCE TEACHERS

At the Chicago meeting of the American Association for the Advancement of Science, the Council took action instructing the A.A.A.S. Committee on the Place of Science in Education to organize a one-day program for those interested in science teaching. This program will be presented in Boston during the winter meetings of the A.A.A.S., and will probably be on Friday, December 29, 1933. Delegates and individual members from all science teachers organizations throughout the country are invited to attend this meeting. All science teachers organizations interested in being represented at the Boston meeting, or individuals who may wish to attend, may secure further information regarding the program by writing to the Committee on the Place of Science in Education, American Association for the Advancement of Science, Smithsonian Institution Building, Washington, D. C. It is expected that the program will be printed in magazines during the autumn.

This program is being organized as a result of various suggestions concerning a national federation of science teachers. The program will be arranged by the Committee on Place of Science in Education, though that committee has no recommendations to make concerning the federation.

SOLUTION OF PROBLEMS FROM EQUATIONS

By R. W. Borgeson
Iowa State College, Ames, Iowa

A chemical equation—is a combination of symbols, formulae and signs that represents a chemical reaction. It is a shorthand representation, (in characters familiar to the chemist), of what takes place during a chemical reaction.

To be as nearly a complete character representation as possible, a chemical equation should show any special conditions necessary to carry out the reaction. These may be temperature, pressure, presence of catalyst or some other special condition. If no special conditions are indicated it is assumed that the reaction will proceed as represented, under ordinary laboratory conditions.

To illustrate—

$$O_2 + N_2 \rightarrow 2NO. \tag{1}$$

We all know that oxygen and nitrogen do not combine under ordinary conditions. (For is not the atmosphere which we breathe 21% O_2 and 79% N_2 by volume?)

But—

$$O_2 + N_2 \xrightarrow[\text{temp. } 3500°\text{C.}]{\text{elec. arc (distorted by mag. field)}} 2NO \tag{1}$$

$$2NO + O_2 \xrightarrow{50°\text{C.}} 2NO_2 \tag{2}$$

$$H_2O + 3NO_2 \rightarrow 2HNO_3 + NO. \tag{3}$$

Here we have indicated the special conditions necessary for the reactions to take place and the equations are "complete." On the other hand—

$$Zn + H_2SO_4 \rightarrow H_2\uparrow + ZnSO_4. \tag{4}$$

We know this reaction goes as indicated under ordinary conditions so long as both H_2SO_4 and Zn are present in contact with each other. As soon as either is used up the reaction will cease.

It should be noted here that, inasmuch as most chemical reactions are carried out in aqueous solutions, the presence of H_2O is not indicated in the equation—unless it (H_2O) is one of the reacting compounds or one of the products formed. In other words we do not write—

$$Zn + H_2SO_4 + H_2O \rightarrow \overset{\uparrow}{H_2} + ZnSO_4 + H_2O \qquad (5)$$

but more briefly indicate the reaction as in equation (4).

Explanation of signs

$+$ signifies addition of; and
$\rightarrow$ indicates the normal direction of reaction
$\rightleftarrows$ indicates that the reaction products react with each other to re-form the original, a state of equilibrium resulting
$\uparrow$ a gas which escapes
$\downarrow$ a precipitated body
$\triangle$ symbol for heat
$\rightarrow$ equivalent to, i.e. (will react with
or (produces
$\leftarrow$ (requires

What does a chemical equation indicate?

Qualitatively—it indicates the reacting substances and the substances produced or formed during the reaction.

Quantitatively—it indicates a definite weight of some compound that will react with a definite weight of another—and also shows the weights of the various products that will be formed when these *chemically equivalent* weights of the reacting compounds have been completely changed over to the new compounds (products of the reaction). Consider the equation—

$$Zn + H_2SO_4 \rightarrow \overset{\uparrow}{H_2} + ZnSO_4. \qquad (4)$$

Here we are shown that one atom of zinc reacts with one molecule of H_2SO_4 to form one molecule of hydrogen and one molecule of $ZnSO_4$.

Atoms, and hence molecules, have definite mass or weight.

What is the weight of an atom? That depends on the element.

Individual atoms of different elements have different weight even as various objects and quantities of matter that we meet with in every day life.

We have a means of distinguishing or determining the weights of masses of these objects. For this purpose man has evolved a system, taking some defined unit, for comparing the masses of objects and quantities of matter. We say a certain man weighs 125 pounds and another man weights 250 pounds. Instantly we recognize that the second man is two times as heavy as the first.

The unit of weight in the English system is the pound. How much is a pound? It is the weight of a cylinder of pure platinum 1.35 inches high having a diameter of 1.15 inches. (Note: For the evolution of the "pound" see some standard encyclopedia.) This then gives us a standard for comparing the masses of different objects and quantities of matter.

Similarly the weights of the atoms of the elements are determined. The weight of an atom of oxygen has been chosen as the standard for weighing atoms. An atom of oxygen is given a weight of sixteen. Sixteen what? Sixteen "atomic weight units." Therefore, the unit for measuring the mass of atoms is 1/16 the weight of an atom of oxygen—and is called "the atomic weight unit."

There should be no hesitancy in accepting this term nor difficulty in comprehending it.

If we had a single, more concrete term to signify this value as we have in our other systems of weights and measures—much of the vagueness and difficulty now obvious in explanations of atomic weights would disappear.

Suppose we give a name to this term "atomic weight unit," and call it an "ātun." Then an atun would be defined as "the atomic weight unit," equal to 1/16 the weight of an atom of oxygen.

Let us consider 1/16 of a pound as the unit of avoirdupois measure. 1/16 of a pound is called an ounce—but it is also then "the avoirdupois weight unit," the unit for measuring weights of ordinary commodities in the English system.

Similarly "the atomic weight unit" or atun is the unit for measuring the weight of atoms. Then an atom of oxygen weighs 16 atuns—even as a pound weighs 16 ounces.

From careful experimentation the weights of the atoms of all the elements have been determined as compared to the weight of an atom of oxygen. This then gives them definite weights in terms of atuns.

These weights we now know, and they are called "atomic weights." The atomic weight of oxygen is 16, that is, an atom of oxygen weighs 16 atuns. An atom of nitrogen weighs 14 atuns, of sulfur 32 atuns, of vanadium 51 atuns, of bismuth 208 atuns, etc. etc.

Since a molecule is a chemical combination of atoms—and the weights of these atoms do not change when they combine to form molecules—then the weight of a molecule is equal to the

sum of the weights of all the atoms of which it is composed. The weight of a molecule of any substance may then be expressed in atuns.

Let us now return to equation (4)

$$Zn + H_2SO_4 \rightarrow H_2\uparrow + ZnSO_4. \qquad (4)$$

Since we know that atoms and molecules have weight and have agreed on a unit for expressing these weights, we may now interpret the above equation as follows—65.37 atuns of zinc reacts with 98.06 atuns of H_2SO_4 to form 2 atuns of hydrogen and 161.43 atuns of $ZnSO_4$.

To the chemist, a symbol or formula represents not only an atom of some element or a molecule of some compound—but also represents a definite weight of the substance indicated,—namely, the atomic weight or molecular weight, as the case may be. Thus, Zn represents more than just an atom of zinc. It stands for Zn (65.37) atuns of zinc, and H_2SO_4 represents H_2SO_4 (98.06) atuns of hydrogen sulfate.

We shall now proceed to the solution of a simple problem.

Problem 1

How many grams of H_2SO_4 will be required to dissolve 100 g. of pure zinc?

1st step

Write and balance the equation for the reaction

$$Zn + H_2SO_4 \rightarrow H_2\uparrow + ZnSO_4. \qquad (4)$$

2nd step

Indicate the weight relation from the equation involving only the substances mentioned in the problem.

$$\text{Zn atuns (of Zn)} \longrightarrow H_2SO_4 \text{ atuns (of } H_2SO_4) \qquad (6)$$

then

$$\text{Zn g. (of Zn)} \longrightarrow H_2SO_4 \text{ g. (of } H_2SO_4) \qquad (8)$$

(see note) $\quad$ or $\text{Zn lbs. (of Zn)} \longrightarrow H_2SO_4 \text{ lbs. (of } H_2SO_4)$. (10)

3rd step

Find the weight of one of the substances that reacts with or produces a UNIT weight of the other

then from equation (8)

$$1 \text{ g. Zn} \longrightarrow \frac{H_2SO_4}{Zn} \text{ g. of } H_2SO_4.$$

4th step

Find the total weight required or produced for the weight indicated in the problem

$$100 \text{ g. Zn} \longrightarrow \frac{H_2SO_4}{Zn}(100) \text{ g. of } H_2SO_4.$$

Since an atun is a definite weight unit there must be a certain *very large number* of atuns required to equal one gram. This number is $(6.062(10^{23})$ commonly known as Avogadro's number —the number of atoms present in a gram atomic weight of an element. Let us represent this large number by the letter A. Then 1 gram = A atuns. Dividing equation (6) by A, we have—

$$\frac{Zn}{A} \text{ g. of Zn} \longrightarrow \frac{H_2SO_4}{A} \text{ g. of } H_2SO_4. \tag{7}$$

Multiplying equation (7) by A, we have—

$$Zn \text{ g. (of Zn)} \longrightarrow H_2SO_4 \text{ g. (of } H_2SO_4). \tag{8}$$

Similarly—

Dividing equation (8) by 453.6 (No. grams in one pound), we have—

$$\frac{Zn}{453.6} \text{ lbs. (of Zn)} \longrightarrow \frac{H_2SO_4}{453.6} \text{ lbs. (of } H_2SO_4) \tag{9}$$

and multiplying equation (9) by 453.6, we have—

$$Zn \text{ lbs. (of Zn)} \longrightarrow H_2SO_4 \text{ lbs. (of } H_2SO_4). \tag{10}$$

Thus we see that any system of units may be used to indicate weights of substances appearing in the equation.

Volume Relationships

From equation (4) we note that H_2 grams of hydrogen is formed. It has been experimentally shown that $H_2(2.016)$ grams of hydrogen occupies a volume of 22.4 liters of 760 mm. pressure and 0°C., which is referred to as standard conditions (S.T.P.) It has also been proved that 22.4 liters is the volume of a mole (gram-molecular weight) of *any* gas at S.T.P. Therefore it is possible from the weight-volume relation given by the equation

and from the laws of Boyle and Charles to calculate volume relationships and volumes of gas produced or required for any given problem.

Problem 2

How many liters of pure hydrogen will be formed at 750 mm. and 20°C., by the action of an excess of dilute H_2SO_4 on 100 g. of pure zinc?

Solving in steps, as under Problem 1.

$$Zn + H_2SO_4 \rightarrow H_2 + ZnSO_4 \qquad (4)$$

$$Zn \text{ g. (of Zn)} \rightarrow 22.4 \text{ L. } H_2 \text{ at S. T. P.}$$

$$1 \text{ g. Zn} \rightarrow \frac{22.4}{Zn} \text{ L. } H_2 \text{ at S. T. P.}$$

$$100 \text{ g. Zn} \rightarrow \left(\frac{22.4}{Zn}\right)(100) \text{ L. } H_2 \text{ at S. T. P.}$$

At

$$\left\{\begin{array}{l} 750 \text{ mm. } 100 \text{ g. Zn} \rightarrow \left(\frac{22.4}{Zn}\right)(100)\left(\frac{760}{750}\right)\left(\frac{293}{273}\right) \text{ liters } H_2 \\ 20°\text{C.} \end{array}\right.$$

Problem 3

How many gallons of $C_{12}H_{26}$, sp. gravity 0.81, can be burned to CO_2 and H_2O by 1000 cu. ft. of air (21% O_2), at 740 mm. and 20°C?

1 gallon H_2O = 8.4 lbs. 1 pound = 453.6 g. 1 cu. ft. = 28.32 L.

(1) $2\ C_{12}H_{26} + 37\ O_2 \xrightarrow{\triangle} 24\ CO_2\uparrow + 26\ H_2O\uparrow$ (11)

(2) $2\ C_{12}H_{26}$ g. (of $C_{12}H_{26}$) $\rightarrow (37)\ (22.4)$ L. O_2 at S. T. P.

(3) $\dfrac{2\ C_{12}H_{26}}{(37)\ (22.4)}$ g. of $C_{12}H_{26} \rightarrow 1$ L. O_2 at S. T. P.

(4) We must now change the vol. of air at conditions given, to *liters of* O_2 *at S.T.P.*

$$(1000)\ (28.32)\ (0.21)\left(\frac{740}{760}\right)\left(\frac{273}{293}\right) = \text{L. } O_2 \text{ at S. T. P.}$$

(5) Then $(1000)\ (28.32)\ (0.21)\left(\dfrac{740}{760}\right)\left(\dfrac{273}{293}\right)\dfrac{2\ C_{12}H_{26}}{37\ (22.4)}$

$= B$ grams $C_{12}H_{26}$ that can be burned

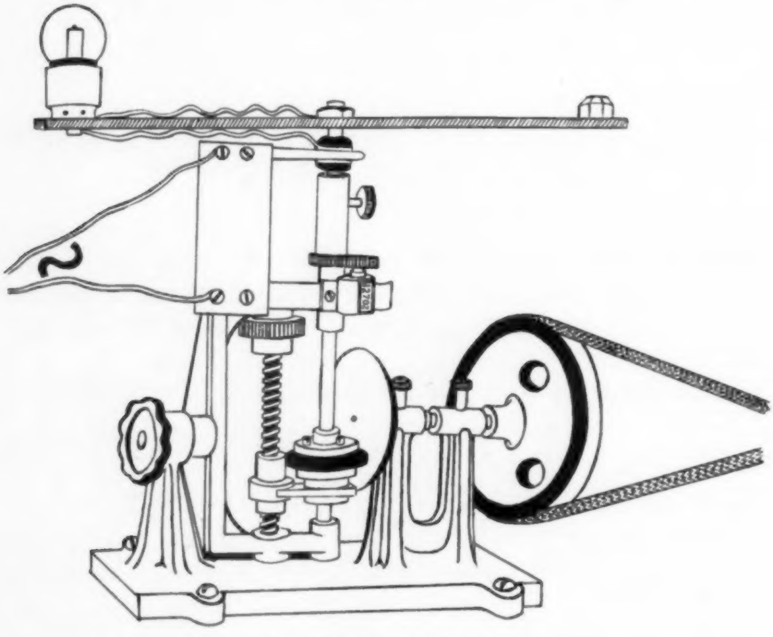
(6) and $\dfrac{B}{(8.4)\,(0.81)\,(453.6)} = C$ gallons $C_{12}H_{26}$

NOTE: $(8.4)(0.81)\ (453.6) =$ weight in grams of 1 gallon $C_{12}H_{26}$.

FREQUENCY OF THE ALTERNATING CURRENT BY VISUAL METHOD

BY DAVID L. COOK
Wheaton College, Wheaton, Illinois

In introducing phenomena connected with the alternating current the author has used two methods that always appeal to students because of their being vivid and concrete. One of



Neon lamp and Rotator

these methods has been shown before in this journal[1] and consists in setting a light copper wire to vibrating in loops when carrying an alternating current perpendicular to a magnetic field. This is very similar to Melde's method for finding the fre-

[1] School Science and Mathematics, October, 1929.

quency of a tuning fork by counting the number of loops in a silk cord that holds a light weight suspended from one prong of the fork.

In connection with the above method which may be used to get the frequency of the alternating current with fair accuracy, we have been using a small neon lamp on a rotator, so synchronized that the lamp becomes bright at the same point in the circle in every revolution. This is made possible because of the fact that the luminescence in neon gas is quenched at almost the same instant that the potential falls below a certain critical value. If the lamp carrying 60 cycle current is made to rotate 20 times a second, there will appear to be six bright spots corresponding to the six points in its path where the potential has reached a maximum in either direction. Retinal fatigue causes these images to appear as continuous. With a stop watch and a speed counter one may get the revolutions per second. The frequency is found as accurately as one may read these instruments. The number of cycles is equal to the number of revolutions per second multiplied by one half the number of spots.

Neon bulbs made to fit standard lamp sockets and operating at 110 volts can be obtained from most any radio catalogue house.

A STUDENT TEACHER'S POINT OF VIEW

By C. C. Trillingham
Supervisor of Practice Teaching, University of Southern California, Los Angeles, California

In spite of all of the efforts toward educational reorganization in the past two decades, especially in regard to secondary school curricula, there yet remains considerable disagreement among school people as to the particular function of plane geometry as a high school subject. Some progress has no doubt been made in this respect. It is apparent that one of the most forward steps in the improvement of mathematics instruction has been an increasing tendency on the part of mathematics teachers themselves to question the merit of plane geometry as it is very frequently taught. A few years ago, teachers seldom questioned either the content, the method, or the placement of plane geometry. Its widespread traditional use was sufficient to dispel all doubts

The modern philosophy of education which reveals the true purpose and function of the high school in America today, coupled with the findings of educational psychology as to the extremely limited nature of transfer of training, has caused teachers of geometry to ask such questions as:

1. What are the general aims and objectives of plane geometry as a high school subject?

2. What shift should be made in the content of geometry, and what new emphasis should be made as to methodology?

3. What students should study plane geometry?

4. What general changes should be affected in order that the study of plane geometry might be most worth while in the lives of high school students?

Teacher training institutions are doing their part in this rejuvenation of high school geometry. With the best evidence of educational philosophy, history, and psychology available, opportunity is today offered the "teacher-to-be" to study the place of plane geometry in the curriculum, to organize courses of study therein, and a chance to get actual teaching experience under the supervision of an experienced, well-trained teacher. One of our most capable student teachers during the Fall semester of 1932 at the University of Southern California, submitted a statement at the conclusion of his practice teaching program which reveals his conviction that improvement in the status of high school geometry must be carried still further. It strikes me that this student's point of view, which is but a single possible suggestion, is worth passing on, as it so adequately illustrates the problem that is perplexing both experienced and embryo teachers of geometry at the present time:

"Since psychology now insists that transfer of training is neither extensive nor automatic, mathematics has lost one of its old justifications—that it would train in reasoning, analysis and synthesis, and that this training could be applied to other problems of life. On these traditional grounds, high school geometry was accorded the place of a compulsory study. However, it is now admitted that practical applications of geometry are somewhat limited, but with the characteristic lagging of educational practice behind educational teaching theory, plane geometry is still one of the solid, academic subjects. It is compulsory in many high school courses, and is presented to a student whether he is brilliant or deficient, with little regard for his needs in actual life.

"The experience of mathematics, if it is still insisted that all should at least taste it, should be given in a course of general mathematics in the junior high school, but this course should be elementary in content, and informal in presentation, with a practical application of the subject as the largest aim. As general mathematics is now taught in junior high schools, this is usually not the case. It has tended to become merely a lowered form of theoretical mathematics, concentrating in one year's work in junior high school the first two years' work of high school mathematics.

"After all have had this experience in junior high school mathematics, the students who should study geometry in high school should be included in one of the following groups: (a) those who need geometry for college entrance requirements; (b) those who plan to enter engineering and surveying fields; (c) those who plan to enter higher mathematics; and (d) those who plan to enter scientific education.

"Obviously the classes formed of these groups should be of superior intelligence. The high school has too long formed its courses of study to conform with the lesser abilities at the expense of the brighter pupils. The teacher of this course in geometry should take the attitude that the less able student should be ejected as soon as possible; that it is better for him, and for the school, to use his time on some subject where the practical good resulting may be more quickly realized. The practical uses of geometry are not realized until several years later when the student has had an opportunity to apply the fruits of geometry to his chosen field. For instance, it is absurd to teach the measuring of distance by use of plane geometric principles in plane geometry, when that is offered under the subject of surveying and is learned much more quickly when the study of surveying is taken.

"It follows, therefore, that the aims of a course in plane geometry should be the aims of these selected groups of students. The largest aims will be: (1) to develop the knowledge of fundamentals of plane geometry for use in higher mathematics and engineering fields, and for college entrance requirements; (2) to develop the habit of clear, accurate, and precise expression, and to give training in logical, scientific reasoning; (3) to give an appreciation of geometry as used in art, nature, and industry; (4) to give some knowledge of the historical development of mathematics; and (5) to develop some under-

standing of the mathematical controversies in current events. The last four of these are subsidiary aims.

"The need for the fulfillment of these aims for any such selected student as would be taking the course is obvious. The course should be distinctly a foundation course; a course to emphasize the use of geometry as a fundamental concept that must be grasped before later courses extend the usefulness of the subject.

"The average geometry textbook is not good as used at present in many high schools where geometry is offered to all students, but many of them would be excellent texts for the use of superior students. The sequence of the matter offered is frequently illogical to the student, and the proofs and originals are quite often too difficult for any but the bright student. Moreover the pace is usually too rapid, and the corollaries are often too complicated and not clearly connected with the theorems. The average textbook does excellently for the higher grade students, for these reasons—it is full of challenging and novel problems, it is mature and advanced in its attitude, and it expects a lot from its students. But restrictions should be placed upon the student personnel."

Although the above point of view is in direct contrast with that of those who maintain that plane geometry should be offered to practically all students, but with a broader, more generalized and liberalized content, it does indicate that new teachers are possessed of considerable independence of thought which should lead to improved teaching.

THE HYDROGEN TWINS

One of science's most interesting discoveries of recent years is that familiar hydrogen, one of the most prevalent of elements, has a double-weight twin, a variety that has a mass of two instead of one like the common sort.

The strict way of classifying them as hydrogen isotope of mass one and hydrogen isotope of mass two are much too lengthy for common usage. Prof. Harold C. Urey of Columbia University, on behalf of the discoverers of heavy weight hydrogen proposed the names "protium" and "deuterium," but Prof. Gilbert N. Lewis and Ernest O. Lawrence of the University of California call the heart or nucleus of the heavy hydrogen atom "deuton," as contrasted to the common name for the heart of the light hydrogen, "proton."

Prof. William D. Harkins of the University of Chicago has taken the "neutron," that electrically uncharged particle of mass equal to the proton, discovered last year by Dr. James Chadwick in Cambridge, England, and has considered that all the "neutrons" in the universe make up a new chemical element of atomic number zero. For this element he proposed the name "neuton."—*Science Service.*

"WHAT GOOD IS PHYSIOGRAPHY?"

BY EDW. A. C. MURPHY
Senior High School, Westfield, New Jersey

If the knowledge that a pupil gets in high school can be made to be of some use to him, it is obvious it will stay with him longer and be of more interest to him than would otherwise be the case.

"What is the good of this?" is a frequent pupil's question, with which all teachers are familiar.

It may refer to mathematics, a language, a social study, or a science. If the answer to that question is obvious to the pupil, if the subject functions in his daily life, if it is valuable not only as a help toward getting into a higher school, if its practical application is evident, it has a great advantage over purely theoretical knowledge. It is self-evident to any one who has taught pupils of high school age over an extended period of time, that few of them have the minds of research scholars and the overwhelming marjority are "from Missouri" and must be conscious of some immediate or practical use for a subject to be very much interested in it.

With this attitude as a sort of philosophy of teaching, I have endeavored to see to it that the answer to the usefulness, the practical application of physiographical knowledge would be so obvious that the question of "what is the use of it?" would not be asked.

The method was as follows:

1. Pupil participation is solving practical problems.
2. Re-discovering facts of science.
3. Doing field work.
4. Emphasizing strikingly paradoxical, physiographical truths.
5. Using the radio broadcasts and moving pictures.
6. Studying at museums.

I. REAL PROBLEMS IN PHYSIOGRAPHY

Object: To study the relative humidity in the class room for a period of a month, to compare it with the relative humidity out doors for the same period. A Mason's-form hygrometer was used by all pupils in making observations. The readings covered twenty school days in January and February. In the room was one large steam radiator and one Peerless Heating and Ventilat-

ing Unit. The windows were left closed, during the period of experimentation. The results were as follows:

Maximum Relative Humidity in room	48	
Minimum " " " "	27	*Average* 37%
Maximum Outdoor Humidity	91	
Minimum " "	44	*Average* 64%

We found from a United States Weather Bureau map that the yearly average relative humidity out doors for the whole United States is 60%, over the ocean about 85%, and that 35% was essentially a desert condition. We also learned from Huntington *Civilization and Climate* that with a temperature of 70° F. (our average classroom temperature) average relative humidity of less than 60% is very undesirable from the standpoint of mental and physical energy and health.

We then made a series of observations covering twelve days with the heating and ventilating unit turned off and found the average relative humidity 40%.

From these facts we concluded (1) the heating and ventilating unit was effective as a heater but tended to slightly lower the relative humidity in the room rather than to heighten it as it was expected to do, (2) we were studying under desert conditions of humidity.

By a subsequent series of observations we found by putting a large wick (blanket) in the heating unit water-pan and putting a four gallon tank of water on the radiator with a wick (bath towel) in it, and by opening the window slightly so a draft would blow over our improvised humidifier, and by opening other windows slightly but frequently we could maintain over a period of twenty days the following:

maximum indoor	57%	Average 45%
minimum "	40%	

For the same days

maximum outdoor	88%	Average 67%
minimum "	44%	

It will be seen that the outdoor averages compare closely (64–67), while the classroom percentage increased from 37 to 45.

While the temperature average, 69° F., in this case, was still too high and the humidity too low it was a distinct improvement.

Another problem of interest was that of finding longitude.

A boy whose father was captain of the "Tusitala," one of the fine old square rigged ships, brought in a sextant. Using an ordinary watch which we arbitrarily set for Greenwich time as a chronometer, we got our own time by watching the sun cross the meridian with the sextant and figured our longitude.

One human trait is to be skeptical of other people's abilities and laugh at their discomfitures providing they are not very serious discomfitures. If you fall down on the ice and are not injured except in dignity the bystanders laugh—if you are a Weather Man and fall down on your weather predictions you are laughed at, too. So persistent is the idea that the Weather Man makes lucky guesses when his predictions come true and is usually wrong that I felt this offered a good field for study.

Our class Weather Bureau was equipped with a mercurial barometer, Mason's Form hygrometer, Jameson's *Weather and Weather Instruments*, which contains directions on interpreting observed conditions especially barometer readings. All pupils kept records of barometer readings and several made weather predictions. One boy made forecasts for one hundred successive school days and correctly forecast conditions twenty-four hours ahead ninety-four times out of the one hundred. The interesting thing in this connection was that after two months of forecasting weather he seldom referred to his book of directions in making predictions. Another thing of interest, the pupils grew to look for the forecast of our own weather bureau and were led to see the real significance and remarkable accuracy of the United States Weather Bureau predictions.

II. RE-DISCOVERING FACTS OF SCIENCE

One day I was driving home in my car when I saw a boy on the sidewalk wildly signalling to me to stop. "I discovered two of Jupiter's Moons last night," he cried. He had a ten-power telescope which he had increased to forty-eight-power by adding on a cardboard length and buying a new lens for the large end. With this telescope, another "home made" one, and a 20-power 58 cm. one, several pupils have seen two of Jupiter's Moons, Venus in different phases, and the rings of Saturn. In this kind of work the usefulness of the knowledge need not be obvious; the thrill of discovery is sufficient unto itself. A pupil's own account of his telescope follows:

My telescope is a simple affair consisting of the brass draw section of an old 8-power instrument joined to a hard rubber tube. The objective

is a 1 1/2 inch in diameter lens of 24 inch focal length, set in the end of a tube. The eyepiece consists of four lenses, three plano convex and one double convex. The objective is simply an old eye glass lens that Mr. Brady, the optician gave me. The draw part of the telescope was given to me by a fellow up the street.

Since the power of a telescope depends upon the action of the two lenses together we compute it by dividing the focal length of the objective by the focal length of the eyepiece. Hence:

$$24 \div 1/2 = 48 \text{ power.}$$

To mount this telescope I have constructed a device that will hold this and several other instruments I have made after my own design. It is a crude but efficient device. At present I am also making an equatorial mount, and a 6-inch reflector of about 8 to 100 (according to eyepiece).

III. FIELD WORK

The 1932 eclipse of the sun offered a chance for first hand study of a subject that had been dealt with in a good deal of detail in class. Several pupiles were able to be in New Englan in the path of totality. One boy made six photographs with his own camera through smoked glass, developing and printing them himself. These were taken at Olamon, Maine and were spaced at intervals of twenty minutes. They were exhibited in the American Museum of Natural History, December 19 to January 8 in the Special Solar Eclipse Exhibit and elicited a complimentary letter to the boy from Dr. Clyde Fisher, Curator of Astronomy.

Our local terrain has an abundance of evidence of glacial markings and many of our pupils became interested in making sketches and rough measurements of the drumlins seen from the Plainfield road and East Broad Street, and in examining glacial boulders, kames and other striking relics of the glacial periods. Also many small stones, and pebbles were brought in by pupils who had gathered them along the countryside on their collecting trips. These were sorted both according to their composition and the natural agents that had helped to shape or transport them.

Cloud formation we could study first hand by just looking out the windows of the classroom. A record of the clouds and wind direction was kept over a period of several days to learn to connect types of clouds with types of weather to see if "mackerel scales and mare's-tails make lofty ships carry low sails." Several pupils tried to get photographs of the most common forms of clouds and two of them succeeded in getting good pictures of cumulus clouds and a fair print of cirro-cumulus.

A rain gauge (U. S. Weather Bureau type) is set up on the fire escape leading from the roof of the school building and pupils take turns in keeping a record of the precipitation for the month. A graph is made of these and all other instrument readings and these records are kept from month to month. A like procedure is followed with outdoor temperature (A Sixés type maximum and minimum thermometer being used) and with outdoor humidity readings and daily barometer readings.

IV. BELIEVE IT OR NOT

A strikingly paradoxical statement often arrests attention and sticks in the memory where a simple statement of the same fact would do neither.

I may say "the base of the tropopause varies in altitude from eleven miles at the equator to four at the poles, while the temperature is $-117°$ F. at the equator and only $-46°$ F. at the same height over the poles." Or I may say "Believe it or not—the coldest place on earth is over the equator."

The above and many other paradoxes of geography developing out of our class work were put on strikingly colored posters by the pupils where they could be seen by all.

Some other interesting ones were:

1. A boy weighs more at the North Pole than at the equator.
2. All horizontal directions are south from the North Pole.
3. An airplane flew in two different directions at the same time.
4. An ocean liner turned a somersalt; no one was hurt.
5. There can be three Sundays in a week.
6. In one boat it was today and tomorrow at the same time.
7. The earth is nearer the sun in winter than in summer.
8. There is no wood in petrified wood.

V. RADIO, MOTION PICTURES, LECTURES

The American School of the Air Science Program, Fridays at 2:30, the American Museum Astronomy Club broadcast Saturdays at 5 p.m., and the regular Science Radio talks of the American Museum, 2:15 Fridays were listened to in school or at home whenever they seemed to promise physiographical interest.

The following films were borrowed from the New Jersey State Museum and shown, and served to graphically illustrate subjects studied in class.

1. Romance of the Skies
2. Romance of the Planets
3. Eclipse of the Sun
4. Tides and the Moon
5. Digging up the Past

VI. MUSEUM STUDY

Membersof the class have visited the American Museum of Natural History to see and study particularly the remarkable meteorite collection, the photographs and models of the stars and planets, and solar and lunar eclipses, and the exhibit of deep sea apparatus including Dr. Beebe's *Bathysphere.*

The Newark Museum has a splendid collection of rocks found in New Jersey and these were studied by a number of pupils while several went to special exhibits.

The U. S. Weather Bureau, in the Whitehall Building, New York City, was visited when we were planning our class weather bureau and much interesting literature was brought back for reference material.

There is another side to the study of physiography—it should, of course, be a source of inspiration. Moreover, there are lots of scientific ideas worthy of discovery and study in and of themselves without any regard to their practical application or utilitarian value.

The question "What's the good of this?" was answered by one boy—"It has helped me win debates with my relations." Another said "I have been made to realize how small the people of this earth are. When we are so interested in something close to us we do not realize about the things of nature which take place in the heavens and on the earth. We think in terms of our small group and that is all the life we see and know. This subject has opened my eyes toward the future. Before, I thought that all the things of science had been covered by the learned men of the world, but now I know they have almost as much to learn as we have. I thought that it would be almost useless to try to make good in a field with such learned men to compete with, but now I begin to think of all the undiscovered things and possibilities, it makes it look much easier."

Or we may say with the banished duke.

"And this our life, exempt from public haunt,
Finds tongues in trees, books in running brooks,
Sermons in stones, and good in everything."

This discussion however has been concerned chiefly with the more practical aspects of physiography.

COMPARATIVE EFFECTIVENESS OF A FREEDOM METHOD AND A CONVENTIONAL METHOD OF TEACHING HIGH SCHOOL GENERAL SCIENCE

By Rudyard K. Bent
University High School
University of Minnesota, Minneapolis, Minn.

THE PROBLEM

The purpose of this experiment was to determine the relative effectiveness of a "freedom" method and a conventional method of teaching high school general science. By "freedom" was meant not commotion, confusion, and license, but rational relief from stultifying traditions and conventionalities and freedom to develop in a social setting one's own best methods and individuality.

THE SET UP

A ninth year general science class in Smithfield, Pennsylvania, High School was divided into two equivalent groups according to sex, mental age, educational age, chronological age, and general scholarship, and scores on the Otis Classification Test, Form A. Table I, displaying the pairing data, shows that the mean classification index for the Control Group was 100, and for the Experimental Group 100.7.

Table I. Pairing Data: Chronological Age, Sex, Educational Age, Mental Age, and Classification Index

	Experimental Group						Control Group					
No.	CA	Sex	EA	MA	IQ	CI	CI	IQ	MA	EA	S	CA
1	14–4	F	16.8	16.0	112	114	119	116	17.0	18.0	F	14–8
2	13–10	M	17.1	15.0	109	115	112	110	15.5	16.2	M	14–1
3	13–11	F	13.6	13.2	105	103	109	113	17.0	15.8	M	15–5
4	15–1	M	15.0	14.5	101	102	100	109	16.0	13.8	F	15–9
5	14–5	M	12.8	14.0	101	96	97	103	14.2	12.4	M	14–0
6	16–2	F	15.1	12.8	89	94	90	95	13.4	12.4	F	15–3
7	15–8	M	12.0	12.2	85	81	73	85	12.0	11.0	M	15–1
Tot.			102	97.7	702	705	700	731	105	99.6		
Avg.	14–9		14.6	13.9	100	100.7	100	104	15	14.2		14–9

The groups met at different periods and were instructed by different methods for six weeks; then the methods were reversed for six weeks further instruction. All other known factors were controlled.

THE METHOD

Experimental Group. No regular text book was used but several texts were placed at the disposal of the class. After deciding upon some unit of work which they wished to pursue, the pupils, with such aid from the instructor as they solicited, made their own plans for study. They determined for themselves which experiments they wished to perform, and each prosecuted his own laboratory work. Complete freedom was allowed them during class periods. Upon entering the classroom each went about his own work, one reading, another experimenting, some conferring over a mental problem, others writing reports, and still others counseling with the instructor. Voluntary industriousness characterized this class. No task was ever imposed upon it.

TABLE II. RESULTS OF THE FIRST THREE UNITS

1	2	3	4
Test No.	Control Group	Experimental Group	$\frac{\text{Difference}}{\sigma \text{ of Dif.}}$
1.	25.57	26.40	.83/2.9= .28
2.	18.42	23.57	5.1/2.8=1.8
3.	37.7	38.7	1.0/2.8= .35
4.	21.5	20.7	.8/2.5= .31
5.	20.57	19.00	1.5/2.5= .61

TABLE III. RESULTS OF THE SECOND THREE UNITS

1	2	3	4
Test No.	Control Group	Experimental Group	$\frac{\text{Difference}}{\sigma \text{ of Dif.}}$
1.	15.6	16.6	1.0/2.3= .42
2.	14.6	15.0	.4/1.2= .31
3.	21.3	20.6	.7/2.0= .34
4.	24.0	22.0	2.0/1.3=1.46
5.	21.0	20.7	.3/2.0= .14

Control Group. What ever work the Experimental Group elected to do was assigned to the Control Group. Each pupil in the latter class was given a text and a laboratory manual, and the assignments. The instructor demonstrated experiments while the pupils observed and made written reports on them.

THE RESULTS

Three units were studied; then the groups were rotated and three other units were pursued.

Results were determined by tests which were administered immediately following each unit for immediate mastery, and two weeks and three months later for delayed recall. The tests were objective in nature, consisting of best-answer items and picture analysis. Ten tests were given in all, six for immediate recall and four for retention. Tables II and III record the tests results. The numbers in columns 3 and 4 represent the means of the scores made by the members of a group on the various tests. They reveal that the Experimental Group excelled on all save one of the tests for immediate recall, while the Control Group was slightly superior on all measures of retention. Although these differences are not significant statistically, as shown in column 4, they have sociological implications.

OBSERVATIONS

The freedom method appeared to be more immediately enjoyable. The challenge of planning and doing seemed to appeal to the pupils.

Since this method provided for individual interests and work, it required more apparatus than the teacher-demonstration procedure necessitates. It also required more time. A vacant period immediately following their regular class period was put at the disposal of the Experimental Group to enable them to keep pace with the teacher-directed class. What ever the by-products that may have accrued to these pupils from planning and executing their own experiments, they lacked the ingenuity and manipulative skill to compete with the instructor in conducting the experiments.

CONCLUSIONS

In the light of the qualitative results of this experiment and of the instructor's observations, it would appear that the method to be employed would depend on the teacher's philosophy and purpose. If general science is meant to be merely ex-

ploratory and to create scientific interest, a considerable degree of freedom may well be allowed. If, on the other hand, the main object of the course is propaedeutic and if the burden of it is mastery of scientific principles fundamental to sequent courses, the subject-matter probably should be dictated and outlined by the teacher and a conventional method of instruction employed.

Regardless of the purpose, however, it is probable that more freedom than is customary may safely be allowed general science pupils in both the planning and the executing of their work. Loss in time and the vexatious frustrations of the trial-and-error method may be more than compensated for in the larger opportunity which a relatively free method affords.

After all, the particular way of getting a thing done may not be as important in the long run as is the getting of it done. The patient teacher of general science will be rewarded with a surprising amount of pupil ingenuity. A poor pupil, for example, who was unable to provide standard equipment for a certain experiment devised her own way of performing it. With such materials as she could find in the laboratory and around home—a flower pot, a water bucket, a tin can, an automobile tire pump, and some rubber hose and glass tubing—she improvised and demonstrated a city water system.

Nevertheless, the increased demands made upon laboratory facilities under any individual-project system constitutes a heavy burden upon the small high school. The evidence adduced by the present experiment and confirmed by those of Keible and Woody,[1] Anibal,[2] Cooprider,[3] Cunningham,[4] Johnson,[5] and Wiley[6] suggest that when laboratory facilities are necessarily meager, it is better for the teacher to demonstrate science experiments effectively than for pupils to experience them ineffectively.

---

[1] Kiebler and Woody. The Individual Laboratory versus the Demonstration Method of Teaching Physics. *Journal of Educational Research.* 7: 50–59, January, 1923.

[2] Anibal, F. G. The Effectiveness of Different Methods of Teaching High School Chemistry. *Journal of Educational Research*, 19: 355–65, May, 1926.

[3] Cooprider, J. L. Oral versus Written Instruction and Demonstration versus Individual Work in High School Science. *School Science and Mathematics*, 22: 838–44, December, 1922.

[4] Cunningham, H. A. Individual Laboratory Work versus Lecture Demonstration in High School Science. *School Science and Mathematics*, 24: 709–715 and 848–851, October and November, 1924.

[5] Johnson, Palmer O. A Comparison of the Lecture-Demonstration Individual Laboratory Experimentation, and Group Laboratory Experimentation Methods of Teaching High School Biology. Master's Thesis, College of Education, University of Minnesota, 1926.

[6] Wiley, W. H. An Experimental Study of Methods of Teaching High School Chemistry. *Journal of Educational Psychology*, 9: 181–198, April, 1918.

LET'S GO

On To Chicago December 1 and 2, 1933

More than ever before it is imperative that you attend the Chicago Convention of the *Central Association of Science and Mathematics Teachers* if you expect to keep pace with the rapid strides being made in mathematics and science. A Century of Progress in these fields has wrought many changes in content and methods of teaching, and in spite of present day reverses in the field of education, it is essential that all teachers gather for the purpose of learning about these new methods and new ideas from outstanding experts and teachers. The Central Association provides such a gathering place each year and furnishes the very best talent that can be procured to address teachers and stimulate among them discussions of current problems of great importance.

Teachers leave these meetings with an inspiration that makes it possible for them to attack both old and new problems with renewed vigor. They carry away with them memories of ringing addresses by prominent leaders in their respective fields and are stirred by the phenomimal demonstrations that are given every year. Above all, the new contacts made with teachers from other sections of the country and the consequent exchange of ideas is more than worth the time and money spent in attending one of these conventions.

Beyond a doubt, the *Central Association* carries on its programs the outstanding mathematicians, scientists, educators, and teachers in the country, and the results of many research problems of great importance both in content matter and classroom procedure are presented. The association also publishes a journal, SCHOOL SCIENCE AND MATHEMATICS, the only journal of its kind in the country and conceded to be one of the outstanding publications. In view of these facts it is difficult to see how any progressive teacher can afford to miss these meetings. And it may be stated here, that the 33rd convention promises to be one of the most inspiring if not the greatest of meetings so far held. So make your plans now to come to Chicago and bring your friends along. They will be indebted to you forever if you induce them to accompany you to this convention.

The President of the Association is happy to announce at this time that the following prominent leaders in mathematics, science, and education will appear on the program.

1. Prof. Arthur H. Compton, University of Chicago renowned physicist and Nobel Prize winner.
2. Mr. William J. Bogan, Superintendent of Schools Chicago, Ill.
3. Prof. Charles Hubbard Judd, Chairman of the Department of Education, University of Chicago, outstanding educator and silver-tongued orator.
4. Prof. Joseph F. Gonnelly, District Supt. of Schools, Chicago, Ill.
5. Prof. Chas. S. Schlicter, Dean of the Graduate School and Professor of applied Mathematics, University of Wisconsin.
6. Dr. M. M. States, Central Scientific Co., Chicago, Ill.
7. Dr. E. R. Breslich, University of Chicago, authority on the pedagogy of mathematics.
8. Mr. James E. McDade, Asst. Supt. of Schools, Chicago, Ill.
9. Prof. Arthur L. Foley, Head of Dept. of Physics, Indiana University.
10. Prof. J. Russell Whitaker, Dept. of Geography, University of Wisconsin.
11. Mr. Charles H. Lake, Superintendent of Schools, Cleveland, Ohio.
12. Prof. F. D. Curtis, School of Education, University of Michigan, Ann Arbor, Mich.

The programs for the various sections will be distributed very shortly. On these programs will be found some of our prominent men and women who are accepted as leaders by teachers throughout the country. They are bringing to you the results of many years of labor, experimentation, and thinking.

Reach for your calendar now and encircle the dates December 1 and 2 to remind you of the coming convention. You absolutely cannot afford to miss this remarkable gathering and program. There is also every reason to believe that many of the great scientific exhibits at the Century of Progress will remain intact when the Association meets. If you have not seen these wonderful displays, now is the time to do so. Tell your friends about the meeting and urge them to come. Remember there is a great treat in store for you and your friends.

For information concerning special railroad and hotel rates call or write the following state representatives of the Association:

Indiana. Mr. Walter Gingery, Prin. Washington High School, Indianapolis.
Mr. Ersie S. Martin, Arsenal Technical High School, Indianapolis.

Illinois. Mr. Glen W. Warner, Editor, SCHOOL SCIENCE AND MATHEMATICS, 7633 Calumet Ave., Chicago.
Mr. G. T. Franklin, Lane Technical High School, Chicago.

Wisconsin. Mr. Ira Davis, University High School Madison.
Mr. W. F. Roecker, Business Manager, SCHOOL SCIENCE AND MATHEMATICS, 3319 N. 14th St., Milwaukee.

Michigan. Mr. C. L. Thiele, Board of Education, Detroit.
Mr. Harvey M. Milford, Edwin Denby High School, Detroit.

Ohio. Mr. E. O. Bower, East Technical High School, Cleveland.
Mr. Frank R. Bemisderfer, East Technical High School, Cleveland.

Missouri. Mr. W. R. Teeters, Board of Education Building, St. Louis.
Mr. Leonard D. Haertter, John Burroughs High School, Clayton.

Pennsylvania. Mr. J. Albert Foberg, State Teachers College, California.
Mr. M. G. Schucker, Peabody High School, Pittsburgh.

PROPOSED AMENDMENT TO THE BY-LAWS

Amendment XII—Article 4, Section 2, shall be amended to red as follows:

"*Section 2. Number:* There shall be fifteen (15) members of the Board of Directors. The President, the Vice-President, and the President of the preceding year shall be ex-officio members of the Board of Directors. The remaining members of the Board of Directors shall be divided into three groups of four (4) directors each. The first Board of Directors shall be so chosen that members of the first group shall serve three years; members of the second group, two years; and members of the third group, one year. Thereafter four directors shall be elected annually to succeed those of the group whose terms are about to expire."

Slavery is but half abolished, emancipation is but half completed, while millions of freemen with votes in their hands are left without education.—WINTHROP.

PROBLEM DEPARTMENT

CONDUCTED BY G. H. JAMISON
State Teachers College, Kirksville, Mo.

This department aims to provide problems of varying degrees of difficulty which will interest anyone engaged in the study of mathematics.

All readers are invited to propose problems and to solve problems here proposed. Drawings to illustrate the problems should be well done in India ink. Problems and solutions will be credited to their authors. Each solution, or proposed problem, sent to the Editor, should have the author's name introducing the problem or solution *as on the following pages.*

The Editor of the department desires to serve its readers by making it interesting and helpful to them. Address suggestions and problems to G. H. Jamison, State Teachers College, Kirksville, Missouri.

SOLUTIONS OF PROBLEMS

Note. Persons sending in solutions and submitting problems for solution should observe the following instructions:

1. Drawings in india ink should be on a separate page from the solution.

2. Give the solution to the problem which you propose if you have one and also the source and any known references to it.

3. In general when several solutions are correct, the one submitted in the best form will be used.

LATE SOLUTIONS

1265. William W. Taylor, Commerce, Texas.

1275. Charles W. Trigg, Los Angeles, Calif.

1280. *Proposed by Frank B. Allen, Sparta, Illinois.*

Find the sum of the series: $1-\frac{1}{5}+\frac{1}{7}-\frac{1}{11}+\cdots$

Solved by Joseph Lev, Ithaca, N. Y.

Write the terms of the given series as coefficients of a power series. Then for $0<x<1$

$$x-\frac{x^5}{5}+\frac{x^7}{7}-\frac{x^{11}}{11}+\frac{x^{13}}{13}-\cdots=\int_0^x(1-x^4+x^6-x^{10}+x^{12}-x^{16}+\cdots)dx$$

$$=\int_0^x(1-x^4)(1+x^6+x^{12}+\cdots)dx=\int_0^x\frac{(1-x^4)}{1-x^6}dx$$

$$=\frac{1}{\sqrt{3}}\left(\tan^{-1}\frac{2x-1}{\sqrt{3}}+\tan^{-1}\frac{2x+1}{3}\right)=\frac{1}{\sqrt{3}}\tan^{-1}\frac{x\sqrt{3}}{1-x^2}$$

Then by Abel's theorem

$$1-\frac{1}{5}+\frac{1}{7}-\frac{1}{11}+\frac{1}{13}-\cdots=\lim_{x\to 1}\frac{1}{\sqrt{3}}\tan^{-1}\frac{x\sqrt{3}}{1-x^2}=\frac{\pi}{2\sqrt{3}}.$$

Also solved by Howard D. Grossman, Brooklyn, N. Y. and the proposer.

1281. *Proposed by Charles Louthan, Columbus, Ohio.*

A vessel is anchored a miles off shore. Opposite a point m miles farther along the shore, another vessel is anchored b miles from the shore. A boat

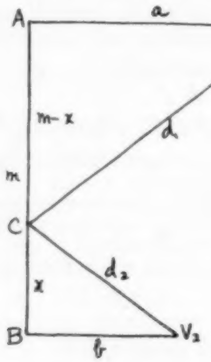
from the first vessel is to land a passenger on the shore and then proceed to the other vessel. Find the shortest course of the boat.

Solved by Orville A. George, Mason City, Iowa.

$$S = \text{course of boat}$$
$$= d_1 + d_2$$
$$= \sqrt{a^2+(m-x)^2} + \sqrt{b^2+x^2}. \quad (1)$$
$$\frac{dS}{dx} = \frac{x-m}{\sqrt{a^2+(m-x)^2}} + \frac{x}{\sqrt{b^2+x^2}}. \quad (2)$$

Placing (2) equal to zero,

$$(x-m)\sqrt{b^2+x^2} + x\sqrt{a^2+(m-x)^2} = 0. \quad (3)$$



Solving for x:

$$x_1 = \frac{mb}{b-a}, \qquad x_2 = \frac{mb}{b+a}. \quad (4)$$

To test these two values of x for Maximum or minimum values, we get $\frac{d^2S}{dx^2}$.

$$\frac{d^2S}{dx^2} = \frac{a^2}{(a^2+m^2-2mx+x^2)^{3/2}} + \frac{b^2}{(b^2+x^2)^{3/2}}. \quad (5)$$

Substituting $x_1 = \frac{mb}{b-a}$ in (5), we get

$$\frac{d^2S}{dx^2} = -\frac{(a-b)^4}{ab(a^2-2ab+b^2+x^2)1\frac{1}{2}} \quad (6)$$

This is negative for a and b greater than 0, and therefore x_1 gives a maximum.

Substituting $x_2 = \frac{mb}{b+a}$ in (5), gives $\frac{d^2S}{dx^2} = \frac{(a+b)^4}{ab(a^2+2ab+b^2+m^2)^{3/2}}$. (7)

This is positive for a and b greater than zero, and therefore $x_2 = \frac{mb}{b+a}$ gives a minimum, and is the required value.

Substituting this value of x in equation (1), we get the required shortest course of the boat:

$$S = \sqrt{(a+b)^2+m^2}.$$

Also solved by E. J. John and L. E. Hebl, Woodriver, Ill., W. E. Buker,

Leetsdale, Pa., R. T. McGregor, Elk Grove, Calif., John E. Ballards, St. Nazianz, Wis., Cecil B. Read, Wichita, Kan., William W. Johnson, Cleveland, Ohio, Charles W. Trigg, Los Angeles, Calif., and the proposer.

1282. *Proposed by Albert Schwartz, Parth Amboy, N. J.*

Solved by Howard D. Grossman, Brooklyn, N. Y.

Bisect a $\triangle$ by the shortest possible line.

Call the $\triangle ABC$. From C lay off x and a and y on b. Join the extremities of x and y. The conditions that this be the required line are

$$xy=\tfrac{1}{2}ab$$
$$x^2+y^2-2yx\cos C=\text{minimum}.$$

It may be shown by calculus that these conditions are satisfied when $x=y=\sqrt{\frac{ab}{2}}$. Then the line $=\sqrt{ab(1-\cos C)}=\sqrt{ab\left(1-\frac{a^2+b^2-c^2}{2ab}\right)}$ $=\sqrt{c^2-(a-b)^2}=\sqrt{(c-a+b)(c+b-a)}=\sqrt{(s-2a)(s-2b)}$ where $s=a+b+c$. Since there are three such lines, the shortest of them is obtained when a and b are the longest sides of the $\triangle$.

1283. *Proposed by Charles W. Trigg, Cumnock College, Calif.*

"If two internal angle bisectors of a triangle are equal, the triangle is isosceles. Give a direct proof."

First Solution

Solved by Louis Leitner, Manual Training High School, Brooklyn, N. Y.

By the theorem in plane geometry that in any triangle, the square of the bisector of an angle is equal to the product of the two adjacent sides diminished by the product of the segments of the third side, we have the equation

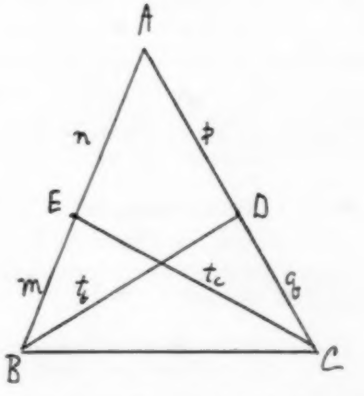
(1) $t_b^2=ac-pq$, or by using the segments of side c, we have

(2) $t_b^2=a(m+n)-pq$. Likewise

(3) $t_c^2=a(p+q)-mn$. But we are given that $t_b=t_c$. Therefore, equating (1) and (2), we have the equation

(4) $a(m+n)-pq=a(p+q)-mn$, or

(5) $am+an-pq=ap+aq-mn$.



Using the theorem that the angle bisectors of a triangle divides the oppo-

site side of the triangle into segments that are proportional to the adjacent sides, we have

(6) $\frac{p}{q}=\frac{c}{a}\cdot$ or $\frac{p}{q}=\frac{m+n}{a}\cdot$ Cross-multiplying, we have

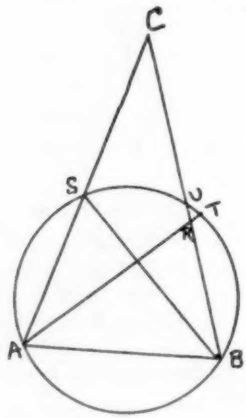
(7) $pa=qm+qn$. Similarly, we have

(8) $an=mq+mp$. Substituting (7) and (8) in (5), we have

(9) $am+mp+mp+pq=mq+qn+aq-mn$. Cancelling the mq in each side of the equation, transposing pq and mn, and factoring the remaining terms gives

(10) $m(a+p+n)=q(a+p+n)$. Dividing through by $a+p+n$, we have

(11) $m=q$. Triangle EBC is congruent to triangle DBC, since $BC=BC$, $BD=CE$, and $CD=BE$ (11). Therefore angle B = angle C. Therefore $AB=AC$. Therefore triangle ABC is isosceles.



Second Solution

By Howard D. Grossman, Brooklyn, N. Y.

Let ABC be the triangle and AR and BS the equal angle bisectors. Circumscribe a circle about A, B, and S. If it passes through R, the proof is immediate. Suppose R is inside the circle. Extend AR till it cuts the circle in T. Let BR cut the circle in U. $\overset{\frown}{AS}=\overset{\frown}{SU}$ and $\overset{\frown}{BT}=\overset{\frown}{ST}$ by equal inscribed angles. Since $\overset{\frown}{ST}>\overset{\frown}{SU}$, then $\overset{\frown}{BT}>\overset{\frown}{AS}$. $\therefore$ $\overset{\frown}{BS}>\overset{\frown}{AT}$ and $\overline{BS}>\overline{AT}$. But $\overline{AT}>\overline{AR}=\overline{BS}$. If R is outside the circle, we have by a similar proof a contradiction. Hence the circle passes through R and the triangle is isosceles.

Third Solution

By Joseph Lev, Ithaca, N. Y.

The following is a direct proof. Using the formulas for bisectors in terms of sides we have from the hypothesis:

$$t_a^2=t_b^2=bc-\frac{ba^2c}{(b+c)^2}=ac-\frac{ab^2c}{(a+c)^2}\cdot$$

This simplifies to

$$(b-a)(b^2c+a^2c+2bc^2+2ac^2+c^3+2abc)=0.$$

Since the second factor is positive

$$b=a.$$

Also solved by John Bellards, St. Nazianz, Wis.

1284. *Proposed by S. Chang, Ping-yang-fu, Shausi, China.*

Solve the pair of equations:

$$xy=x^2-y^2$$
$$x^2y^2=x^3+y^3.$$

Solved by William W. Johnson, Cleveland Ohio.

Given

$$xy=x^2-y^2 \qquad (1)$$
$$x^2y^2=x^3+y^3 \qquad (2)$$

Let

$$x=ay \qquad (3)$$

Substituting (3) in (1), we get

$$ay^2=a^2y^2-y^2, \quad \text{or} \quad y^2(a^2-a-1)=0.$$

Therefore

$$y^2=0, \quad \text{and} \quad a^2-a-1=0.$$

Solving, for a, we find

$$a=\frac{1\pm\sqrt{5}}{2}. \qquad (4)$$

Substituting this value for a in (3), we get

$$x=\left(\frac{1\pm\sqrt{5}}{2}\right)y. \qquad (5)$$

Substituting this value for x in (2), we get

$$y=2. \qquad (6)$$

Substituting the value of y in (6) in (5), we get

$$x=1\pm\sqrt{5}.$$

Therefore the roots which satisfy equations (1) and (2) are:

$$x=1\pm\sqrt{5},$$
$$y=2.$$

Also, $x=0$ when $y=0$.

Also solved by B. Felix John, Pittsburg, Pa., O. A. George, Mason City, Ia., Les Aroian, Fort Collins, Colo., W. E. Buker, Leetsdale, Pa., Charles W. Trigg, Los Angeles, Calif., John E. Bellards, St. Nazianz, Wis., Fred R. Brown, DeWitt, N. Y., Charles P. Louthan, Columbus, Ohio.

Note on problem 1263. E. B. Escott, Oak Park, Illinois, offers such an interesting discussion to this problem that I am giving his discussion in full.

EDITOR

1263. Give a general method for finding integers satisfying the simultaneous equations

$$a+b+c=d+e+f$$
$$a^2+b^2+c^2=d^2+e^2+f^2$$

Take two sets of numbers having equal sums, for example

$$1, 8 \qquad (1)$$

$$4, 5 \qquad (2)$$

Annex to the numbers of the first set, the numbers of the second set increased by any number—say 1. Annex to the numbers of the second set those of the first set increased by the same number. This gives the sets

$$1, 8, 5, 6 \qquad (3)$$

$$4, 5, 2, 9 \qquad (4)$$

Drop all numbers common to the two sets—in this case 5. The resulting sets have their sums equal, also the sums of their squares, i.e.

$$1+6+8=2+4+9$$

$$1^2+6^2+8^2=2^2+4^2+9^2$$

NOTE: If we perform the same operation on these new sets of numbers. we shall have two sets of numbers which have the same sum, sum of squares, and sum of cubes, e.g. increase each set of numbers by 2

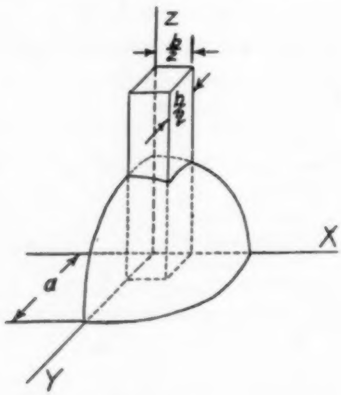
1, 6, 8, 4, 6, 11

2, 4, 9, 3, 8, 10

Drop the numbers common to the two sets, 8 and 4. Then we have 1, 6, 6, 11 and 2, 3, 9, 10 having the same sum, sum of squares, and sum of cubes. This method may be applied indefinitely, e.g. increasing these two sets of numbers by the same number—say by 1, we have after dropping the numbers common to the two sets, 1, 4, 6, 6, 11, 11 and 2, 2, 7, 7, 9, 12 which have the same sum, sum of squares, sum of cubes and sum of 4th powers.

1266. *Proposed by O. T. Snodgrass, Columbia, Missouri.*

Given a sphere of radius "a," and a square shaft, with a side of a cross section of the square, "b." Find the volume cut out by this shaft whose central axis passes through the center of the sphere.



In the figure an octant of the entire sphere and shaft is shown, cylindrical coordinates are used and the limits of the angle θ are 0 and $\frac{\pi}{4}$ · This will cover one sixteenth of the whole volume. The limits of r are 0 and the line

$x=\frac{b}{2}$ or $r=\frac{b}{2}\sec\theta$. Then, by symmetry,

$$V=16\int_{\theta=0}^{\pi/4}\int_{r=0}^{b/2\sec\theta}\int_{z=0}^{\sqrt{a^2-r^2}} rdzdrd\theta$$

$$=-\frac{16}{3}\int_0^{\pi/4}\left[\left(a^2-\frac{b^2}{4}\sec^2\theta\right)^{3/2}-a^3\right]d\theta$$

$$=V=-\frac{16}{3}a^2\int_0^{\pi/4}\sqrt{a^2-\frac{b^2}{4}\sec^2\theta\, d\theta}$$

$$+\frac{8}{3}b\int_0^{\pi/4}\sqrt{\left(a^2-\frac{b^2}{4}\right)-\frac{b^2}{4}\tan^2\theta}\left(\frac{b}{2}\sec^2\theta\right)d\theta+\frac{4}{3}\pi a^3$$

$$=V=-\frac{16}{3}a^2\cdot\frac{b}{2}\int_0^{\pi/4}\sqrt{\frac{4a^2}{b^2}-\sec^2\theta}\,d\theta+\frac{4}{3}b\left[\frac{b}{2}\tan\theta\sqrt{a^2-\frac{b^2}{4}\sec^2\theta}\right.$$

$$\left.+\left(a^2-\frac{b^2}{4}\right)\sin^{-1}\left(\frac{b\tan\theta}{2\sqrt{a^2-\frac{b^2}{4}}}\right)\right]_0^{\pi/4}+\frac{4}{3}\pi a^3.$$

Now in the integral $\int\sqrt{\frac{4a^2}{b^2}-\sec^2\theta d\theta}$, make the substitutions $k=\frac{4a^2}{b^2}$ and $x=\sec^2\theta$.

Then
$$\int\sqrt{\frac{4a^2}{b^2}-\sec^2\theta}\,d\theta=\int\frac{\sqrt{k-x}dx}{2x\sqrt{x-1}}$$

$$=\frac{k}{2}\int\frac{dx}{x\sqrt{(x-1)(k-x)}}-\tfrac{1}{2}\int\frac{dx}{\sqrt{(x-1)(k-x)}}$$

$$=\frac{k}{2}\int\frac{dx}{x\sqrt{(x-1)(k-x)}}-\tfrac{1}{2}\int\frac{dx}{\sqrt{\left[\frac{(k+1)^2}{4}-k\right]-\left[x+\frac{(k+1)}{2}\right]^2}}$$

$$=\frac{k}{2}\int\frac{dx}{x\sqrt{(x-1)(k-x)}}-\tfrac{1}{2}\sin^{-1}\left[\frac{2x-k-1}{k-1}\right].$$

Now in the integral $\int\frac{dx}{x\sqrt{(x-1)(k-x)}}\cdot$ make the substitution $x=\frac{2k}{(k+1)(1+y)}$.

Then this integral equals $-\frac{1}{k}\int\frac{dy}{\sqrt{\left(\frac{k-1}{k+1}\right)^2-y^2}}$

$$= -\frac{1}{\sqrt{k}} \sin^{-1}\left[\frac{(k+1)y}{k-1}\right]$$

$$= -\frac{1}{\sqrt{k}} \sin^{-1}\left[\frac{\frac{2k}{x}-(k+1)}{k-1}\right].$$

Then
$$\int \sqrt{\frac{4a^2}{b^2}-\sec^2\theta}\, d\theta = -\frac{\sqrt{k}}{2} \sin^{-1}\left[\frac{\frac{2k}{x}-(k+1)}{k-1}\right]$$

$$-\tfrac{1}{2}\sin^{-1}\left[\frac{2x-k-1}{k-1}\right].$$

Then
$$V=\frac{4}{3}\pi a^3+\frac{2}{3}b^2\sqrt{a^2-\frac{b^2}{2}}+\frac{4}{3}b\left(a^2-\frac{b^2}{4}\right)\sin^{-1}\left(\frac{b}{2\sqrt{a^2-\frac{b^2}{4}}}\right)$$

$$+\left(\frac{8}{3}a^2b\cdot\frac{\sqrt{k}}{2}\sin^{-1}\left[\frac{\frac{2k}{\sec^2\theta}-(k+1)}{k-1}\right]\right)_0^{\pi/4}$$

$$+\frac{4}{3}\left(a^2b\sin^{-1}\left[\frac{2\sec^2\theta-k-1}{k-1}\right]\right)_0^{\pi/4}$$

$$=V=\frac{4}{3}\pi a^3+\frac{b^2}{3}\sqrt{4a^2-2b^2}+\frac{b}{3}(4a^2-b^2)\sin^{-1}\left(\frac{b}{\sqrt{4a^2-b^2}}\right)$$

$$+\frac{8}{3}a^3\sin^{-1}\left[\frac{b^2}{b^2-4a^2}\right]-\frac{4}{3}\pi a^3+\frac{4}{3}a^2b\sin^{-1}\left[\frac{3b^2-4a^2}{4a^2-b^2}\right]+\frac{2}{3}\pi a^2b,$$

or, finally,

$$V=\frac{b^2}{3}\sqrt{4a^2-2b^2}+\frac{b}{3}(4a^2-b^2)\sin^{-1}\left(\frac{b}{\sqrt{4a^2-b^2}}\right)$$

$$+\frac{8}{3}a^3\sin^{-1}\left(\frac{b^2}{b^2-4a^2}\right)+\frac{4}{3}a^2b\sin^{-1}\left(\frac{3b^2-4a^2}{4a^2-b^2}\right)+\frac{2}{3}\pi a^2b.$$

NOTE: A second solution to this problem submitted by Charles Louthan Columbus, Ohio, will be given in the next issue. EDITOR.

HIGH SCHOOL HONOR ROLL

The Editor will be very happy to make special mention of high school classes, clubs, or individual students who offer solutions to problems submitted in this department. Teachers are urged to report to the Editor such solutions.

For this issue the Honor Roll appears below.

PROBLEMS FOR SOLUTION

1298. Proposed by D. Moody Bailey, Athens, W. Va.

Determine x, y and z so that $x^p y^q z^r$ shall be a maximum if $x+y+z=N$, and p, q, r and N are constants.

1299. Proposed by Walter Penney, Union City, N. J.

Find value of

$$\sqrt{7+\sqrt{1+\sqrt{7+\sqrt{1+\cdots\infty}}}},$$

3 is a value.

the numbers 7 and 1 recurring endlessly.

1300. Proposed by W. E. Bucker, Leetsdale, Pa.

Find the volume of the tetrahedron whose edges are a, b, c, d, e, f.

1301. Proposed by B. C. Becker and L. E. Hebb, Woodriver, Ill.

A small sphere loses its balance at the apex of a larger sphere and rolls off. Neglecting friction, at what angle does its velocity become sufficient for the centrifugal force to carry it away from the larger sphere?

1302. Proposed by Reader.

Given a triangle ABC, $C=90°$. Construct inside this triangle a point N such that $\angle ANB=\angle BNC=\angle CNA$.

1303. Proposed by Charles W. Trigg, Los Angeles, Calif.

A cow is tethered with a 100 ft. rope to a peg on the opposite side of a 10 ft. wall, the peg being 20 ft. from the wall. Find the area over which the cow can graze.

SCIENCE QUESTIONS

October, 1933

Conducted by Franklin T. Jones, 10109 Wilbur Avenue, Cleveland, Ohio.

Please send copies of Tests and Examinations to Franklin T. Jones, 10109 Wilbur Avenue, Cleveland, Ohio.

HALL OF SCIENCE—CENTURY OF PROGRESS

626. (a) Did you visit the Chicago *Century of Progress* Exposition?

(b) Did you make a list of all the experiments?

(c) Did you visit the "House of Magic"?

(d) Are you going home and "put a little more stuff on the ball" to make your science courses interesting?

(e) Were you surprised at the small size of Picard's "Gondola" for exploring the stratosphere?

(f) What else did you see that ought to be called to the attention of readers of SCHOOL SCIENCE AND MATHEMATICS?

"WORK" THIS PROBLEM!

627. *Proposed by J. C. Packard, Brookline, Mass.*

A rectangular block of granite (sp. gr. 2.6), 2 ft. $\times$3 ft. $\times$10 ft., lying flat on the ground upon its narrowest side, is tipped up on end. How much work is done? Note: The block must be eased down into place and not allowed to fall with a jerk. Does it make any difference at what rate this easing down into place is accomplished? Explain fully.

THE ICEBERG PROBLEM

623. *Proposed by Walter E. Hauswald, Beardstown High School, Beardstown, Illinois.*

A glass tumbler is completely filled with ice water (one more drop of water would cause the glass to overflow) and a large cube of ice is floating in the water. Will the glass overflow when the ice melts, or will the water level fall?

Solution by Walter C. Pribnow, Sparta, Wisconsin.

Let us assume that the tumbler has a capacity of 1000 cc., and that the ice has a volume of 100 cc. Then since ice has a S.G. of .917; 1 cc. of it will weigh .917 gm.

$\therefore$ 100 cc. of ice weighs 91.7 gm.

In order to float the ice must lose all of its weight.

$\therefore$ the water displaced =91.7 cc. by volume.

1000 cc. − 91.7 cc. = 908.3 cc. of water in glass and 91.7 cc. of ice in glass is in water.

8.3 cc. of ice in glass is in air.

$91.7 \times .917 = 84.0889$ = cc. of ice water formed when ice under water melts.

$8.3 \times .917 = 7.6111$ = cc. of ice water formed when ice out of water melts.

Total volume of water formed = 91.7000 cc.—or the volume to be replaced with water when all of the ice has melted.

Conclusion: No; the level of the water will neither rise nor fall.

GOLD

620. What is the specific gravity of gold?

A hoarder came into the Federal Reserve Bank at Cleveland with certificates calling for $82,000 in gold coin. How much did it weigh?

Answered by William W. Johnson, Cleveland, Ohio.

The specific gravity of pure gold is: when cast = 19.258,
when hammered = 19.546.

One Gold Eagle equals $10 and weights 258 Troy grains.

One pound Avoirdupois weight = 7000 Troy grains.

Therefore the weight of $82,000 in pounds avoirdupois

$$=\frac{82000 \times 258}{10 \times 7000}$$

$$=\frac{21156}{70}=302\frac{16}{70}$$

$$=302.228 \text{ lbs.}$$

$$=302 \text{ lbs., } 3.66 \text{ ozs.}$$

---

621. "Pop Eye," the sailor, cast his $10,000,000 of gold into a cube to protect it from thieves. How large was the cube?

Answered by William W. Johnson, Cleveland, Ohio.

The specific gravity of pure gold when cast = 19.258.

One Gold Eagle equals $10.00, and weighs 258 Troy grains.

One pound Avoirdupois weight = 7000 Troy grains.

7000 Troy grains = 27.7274 cubic inches of distilled water at 62° F.

Then weight of one cubic foot of water $= \frac{1728}{27.7274} = 62.321$ pounds.

Weight of cast gold per cubic foot = specific gravity × weight of water per cubic foot.
$= 19.258 \times 62.321 = 1200.178$ lbs.

$$\text{Weight of cube of gold in lbs. avoirdupois} = \frac{10,000,000 \times 258}{10 \times 7000}$$

$$= \frac{258,000}{7} = 36,857\frac{1}{7} \text{ lbs.}$$

$$\text{Number of cubic feet in cube} = \frac{258,000}{7 \times 19.258 \times 62.321} = 30.7097 \text{ cu. ft.}$$

Therefore, the length of an edge of the cube $= \sqrt[3]{30.7097}$
$= 3.1315$ feet
$= 3$ ft. $1\frac{37}{64}$ in.

ANOTHER GOLD QUESTION

628. What is the Specific Gravity of a Gold Eagle? (*a*) By Experiment. (*b*) By Calculation.

BIOLOGY TEST JUNE, 1933

629. *Proposed by A. G. Zander, Instructor Boys' Technical High School, Milwaukee, Wis.*

1. A person suffering from a serious stomach ailment had to have his stomach removed.
   a. What class of food would he have to cut down?
   b. This change in diet would benefit another organ. Which one? Why?
2. An otherwise normal person is 4 feet tall. He has been well and properly nourished all of his life. His general health has been good. What might have been the cause, or causes, of his short stature?
3. If some of the middle ribs of a person are seriously injured in an accident what organ might be affected?
4. If you eat a buttered wheat bread ham sandwich which article of food is begun to be digested first and which last? Why?
5. A person is reading an interesting book. A fly is buzzing around his head. He attempts to brush the fly away from time to time without stopping his reading.
   a. Name the parts of the nervous system concerned in the attempt to brush away the fly?
   b. Name the parts concerned in the reading action.
6. The insect is a familiar animal. Name a circumstance under which it might cause death to a human being.
7. In an aquarium at the zoo are found several animals with which you are familiar. Some swim about rapidly but cannot maintain any definite level. When they stop swimming they sink to the bottom unless they can attach themselves to an object, or to another animal. They are parasitic.

Other types of animals are there which swim very rapidly about, are able to stop suddenly, and maintain any depth in the water. Down below, almost always on the bottom, is another animal with a hard outer covering, not moving very rapidly, but able sometimes to move rapidly backwards. In a dark corner of the aquarium is another animal. This fellow is peculiar. He seldom moves his long body and his only manifestation of life is the almost slow movement of two feathery appendages at the sides of his head. He can live on land in moist places but prefers to stay in the water.

Name the animals described in this paragraph.

8. Buzzard; duck; winter resident; insect eater exclusively; robin; wren; chicadee; water fowl; scavenger; eats insects and sometimes eats plant food.

   Pair the words or phrases correctly on the other side of this paper.

9. Which becomes mature earlier in its life a frog or a toad?

10. Why do you suppose that a chicken can rustle its own food when born and a robin cannot?

BOOKS RECEIVED

Educational Biology, by William H. Atwood, Head of Biology Department, Milwaukee State Teachers College, Milwaukee, Wis., and Elwood D. Heiss, Head of Science Department, East Stroudsburgh State Teachers College, East Stroudsburgh, Pennsylvania. Second Edition. Cloth. Pages xiii+475. 269 Illustrations. 15×22.5 cm. 1933. P. Blakiston's Son and Company, Inc., 1012 Walnut Street, Philadelphia, Pa. Price $2.75.

Nature and Science Readers, Book Three—Surprises by Edith M. Patch and Harrison E. Howe. Drawings by Eleanor O. Eadie. Cloth. Pages xiii+307. 13.5×18.5 cm. 1933. The Macmillan Company, 60 Fifth Avenue, New York N. Y. Price 84 cents.

Nature and Science Readers, Book Four—Through Four Seasons, by Edith M. Patch and Harrison E. Howe. Drawings by Eleanor O. Eadie and Mary L. Morse. Cloth. Pages xiv+331. 13.5×18.5 cm. 1933. The Macmillan Company, 60 Fifth Avenue, New York, N. Y. Price 88 cents.

Exercise Book in High School Biology, A Laboratory Workbook with Review Section and Individual Projects, by J. Glenn Blaisdell, Chairman, Biology Department, Charles E. Gorton High School, Yonkers, New York. Paper. Loose-Leaf Form. 167 pages. 20×26 cm. 1933. World Book Company, Yonkers-on-Hudson, New York, N. Y. Price 72 cents.

Plane Trigonometry, by William L. Hart, Professor of Mathematics, University of Minnesota. Cloth. Pages v+186+16+124. Including tables. 14.5×22 cm. 1933. D. C. Heath and Company, 285 Columbus Avenue, Boston, Massachusetts. Price $2.00.

Plants Useful to Man, by Wilfred William Robbins, University of California and Francis Ramaley, University of Colorado. Cloth. 241 Illustrations. Pages vii+428. 14×21 cm. 1933. P. Blakiston's Son and Company, Inc., 1012 Walnut Street, Philadelphia, Pennsylvania. Price $3.00.

The Story of Earth and Sky, by Carleton and Heluiz Washburne in Collaboration with Frederick Reed. Cloth. Pages x+368. 17.5×23 cm. 1933. The Century Company, 353 Fourth Avenue, New York, N. Y. Price $3.50.

New High School Arithmetic, by Webster Wells and Walter W. Hart, Associate Professor of Mathematics, School of Education, and Teacher of Mathematics, Wisconsin High School, University of Wisconsin. Revised. Cloth. Pages viii+357. 12.5×18.5 cm. 1933. D. C. Heath and Company, 285 Columbus Avenue, Boston, Massachusetts. Price $1.52.

Elementary Mechanics of Solids, by H. A. Baxter, Senior Mathematical Master, Liverpool Institute High School, Formerly Scholar of Selwyn College, Cambridge. Cloth. Pages viii+281. 14.5×22 cm. 1933. Messrs. Blackie and Son, Limited, 50 Old Bailey, London, E.C. 4. Price 8/6 net.

Tours Through the World of Science, by William T. Skilling, State Teachers College, San Diego, California. First Edition. Cloth. Pages xiv+758. 12.5×19 cm. 1933. McGraw-Hill Book Company, Inc., 330 West 42nd Street, New York, N. Y. Price $1.70.

Analytic and Vector Mechanics, by Hiram W. Edwards, Associate Professor of Physics, University of California at Los Angeles. First Edition. Cloth. Pages x+428. 14.5×23 cm. 1933. McGraw-Hill Book Company, Inc., 330 West 42nd Street, New York, N. Y. Price $4.00.

Plane Trigonometry, by John A. Northcott, Associate Professor of Mathematics, Columbia University. Cloth. Pages ix+152. 13×20 cm. 1933. Ray Long and Richard R. Smith, Inc., New York, N. Y.

Descriptive Geometry, An Introduction to Engineering Graphs, by F. H. Cherry, Associate Professor of Mechanical Engineering, University of California. Cloth. Pages xi+127. 14×21.5 cm. 1933. The Macmillan Company, 60 Fifth Avenue, New York, N. Y. Price $2.00.

Laboratory Manual to Accompany Principles of General Chemistry, by Erwin B. Kelsey and Harold G. Dietrich, Assistant Professors of Chemistry, Yale University. Revised Edition. Cloth. Pages x+133+73. 14×21.5 cm. 1933. The Macmillan Company, 60 Fifth Avenue, New York, N. Y. Price $1.50.

An Elementary Treatise on Differential Equations, by Abraham Cohen, Collegiate Professor of Mathematics, The Johns Hopkins University. Second Edition, Completely Revised. Cloth. Pages vii+337. 13.5×20 cm. 1933. D. C. Heath and Company, 285 Columbus Avenue, Boston, Massachusetts. Price $2.40.

First-Year Algebra, by Howard B. Kingsbury, West Division High School, Milwaukee, Wisconsin and R. R. Wallace, Calumet Senior High School, Chicago, Illinois. Cloth. Pages x+440. 12.5×18.5 cm. 1933. The Bruce Publishing Company, Milwaukee, Wisconsin. Price $1.32.

Study Guides and Unit Tests to Accompany Living Geography, by M. E. Branom, Head of Department of Geography, Harris Teachers College, St. Louis, Missouri. Paper. Book One, Parts I and II and Book Two, Parts I and II, 4 volumes. 96 pages each. 21×28 cm. 1933. The Macmillan Company, 60 Fifth Avenue, New York, N. Y. Price 20 cents each.

Text Book of College Physics, by C. A. Chant, Professor of Astrophysics and Director of the David Dunlap Observatory, University of Toronto and E. F. Burton Head of the Department of Physics and Director of the Physical Laboratory, University of Toronto. Cloth. Pages xiv+541. 13.5×21.5 cm. 1933. Henry Holt and Company, One Park Avenue, New York, N. Y.

An Introduction to Laboratory Technique in Bacteriology, by Max Levine, Professor of Sanitary and Technical Bacteriology, Iowa State College, Bacteriologist, Iowa Engineering Experiment Station, Ames Iowa. Revised Edition. Cloth. Pages viii+289. 12×19 cm. 1933. The Macmillan Company, 60 Fifth Avenue, New York, N. Y. Price $1.75.

PAMPHLETS RECEIVED

Three Keys to Wild Flowering Plants of Connecticut, Southeastern New York, New Jersey and Eastern Pennsylvania, by Mary Franklin Barrett formerly of the State Normal School and the State Teachers' College, Montclair, New Jersey. Drawings by Marian F. Butts. 46 pages. 15.5×23 cm. 1933. The Independent Press, 64 Park Avenue, Bloomfield, New Jersey.

The Heron, an annual Publication of the Woodmere Academy Bird Club. 42 pages. 19×26.5 cm. 1932. Woodmere Academy, Woodmere, New York.

Electrostatics, A Guide for Use with the Educational Sound Picture, "Electrostatics," Produced for the University of Chicago by the Educational Research Staff of Erpi Picture Consultants, Incorporated, New York City in Collaboration with Harvey B. Lemon and Hermann I. Schlesinger, The University of Chicago. iv+25 pages. 13.5×20 cm. 1933. The University of Chicago Press, Chicago, Illinois.

Energy and Its Transformations, A Guide for Use with the Educational Sound Picture, "Energy and Its Transformations." Produced for the University of Chicago by the Educational Research Staff of Erpi Picture Consultants, Incorporated, New York City in Collaboration with Harvey B. Lemon and Hermann I. Schlesinger, The University of Chicago. Pages iv+26 pages. 13.5×20 cm. 1933. The University of Chicago Press, Chicago, Illinois.

Freshman Mathematics, Book IV, A Brief Introduction to the Calculus, by Hermon L. Slobin and Walter E. Wilbur, The University of New Hampshire. iv+50 pages. 13.5×20 cm. 1933. Ray Long and Richard R. Smith, Inc., New York.

Die Dreiteilung Des Winkels, by Walter Breidenbach. 38 pages. 43 figures. 11.5×18 cm. 1933. B. G. Teubner, Leipzig, Germany. Price R.M. 1.20.

The Parallact, A New Element in Plane Geometry. Discovered and applied by George H. Cooper, Author of The Arithmetic of the Octimal Notation. 14 pages. 11×15 cm. 1932. Cooper and Hillis, 154 South Second Street, San Joan, California. Price 10 cents.

Leitz New Chemical Microscope. Bulletin No. 8. 5 pages. 21.5×28 cm. E. Leitz, Inc., 60 East 10th Street, New York, N. Y.

Leitz Wide Field Binocular Microscope. Bulletin No. 9. 16 pages. 21.5×28 cm. E. Leitz, Inc., 60 East 10th Street, New York, N. Y.

A Simple Technique for Permanent New-Type Tests, by Paul R. Milde, Benedictine School, Savannah, Georgia. 15 pages. 9×16 cm. 1933. Paul R. Milde, 1707 Bull Street, Savannah, Georgia. Price per packet $1.00.

BOOK REVIEWS

A Course in General Chemistry, including an Introduction to Qualitative Analysis, for use in colleges, by William C. Bray, Professor of Chemistry in the University of California, and Wendell M. Latimer, Professor of Chemistry in the University of California. Revised edition. Pp. X plus 159. 15×22×2.2 cm. Cloth. 1932. $1.60. The Macmillan Co.

This revised edition adds to the already excellent method of the older book several sections such as additional work on molal volume, the actual measurement of the electro-motive force of simple cells (in connection with the work on oxidation-reduction reactions) quantitative study of solubility product, chemistry of manganese and the use of permanganate in quantitative analysis, and the preparation and properties of colloids. Throughout the book it is the evident intention of the authors to try to educate the student to apply principles to the solving of problems and to relate the laboratory work and the lecture and reference work thus building up a well rounded unit of science. In the section on qualitative analysis it is apparent that the authors are more concerned in training the student in the building up of a scheme of analysis than in merely teaching him such a scheme as built up by others. The admonition "Be sure that you understand the reason for each detail in the procedure" indicates the spirit of the teaching. Fortunate indeed is the youth who has the benefit of such teaching. College teachers who are seeking up to date laboratory methods will do well to study this revised Course in General Chemistry.

FRANK B. WADE

Principles of General Chemistry, by Stuart R. Brinkley, Associate Professor of Chemistry, Yale University, Revised Edition. Pp. 10 plus 585. 3.5×15.5×22.5 cm. 160 figures. Portraits of noted chemists. Cloth. 1933. Macmillan.

In this real revision of the previous text we have an honest effort to provide a course which is adapted to the student who has had a good course in high school chemistry and who is about to go on in college to get a more comprehensive grasp upon the principles of general inorganic chemistry. After a brief review of the laws of chemical combination and the atomic theory as proposed by Dalton the author treats the periodic system as a means of coordinating the facts studied previously by the pupil and as a background for introducing the newer concepts of atomic structure. With this preparation the modern notions in regard to valence and oxidation-reduction reactions may be easily lead up to. Chemical equilibrium in the gaseous state is studied before equilibrium in solution is taken up. The discussion of ionization is most modern and scientific, the several sets of facts being set forth followed by the Arrhenius theory and then by the modifications of that theory which more recently acquired facts have made necessary. As an example of the way in which the Debye-Hückel view point is conservatively introduced we quote, "The significant point is that in all the reactions which are dependent on the ions in the solution, the effective concentration is less than that which complete dispersion into free ions would furnish."

The descriptive part of the book is classified into groups of similar substances, as "basic oxides," "acidic oxides," "bases," "acids," "salts," etc. The chapters on the metals deal mainly with metallurgy and the principles involved in the extraction of the metals from their ores. While there is some material that may be used in connection with a brief course in qualitative analysis this material concerns itself with the principles used in

the separations rather than with the routine of the separations. Throughout the text, fundamental principles and the application of these general principles are the chief concern of the author. College teachers of general chemistry should see this revised text and high school teachers might profit largely by a close study of it. It should be added to the high school departmental library wherever possible.

F. B. WADE

Volumetric Analysis, by G. Fowles, M.Sc., A.I.C., Assistant Master, Latymer Upper School, Mammersmith. First edition. Pp. 12 plus 202. $2.2 \times 13.5 \times 20$ cm. Some few figures and a colour plate showing indicator colours and pH values. Cloth. 1932. G. Bell & Sons, Ltd. London.

This is an elementary text-book of volumetric analysis and one which may be commended as modern in its treatment of the principles of chemistry which are made use of in the procedure. The first chapter gives an introductory discussion of standard solutions and of the methods of preparing normal solutions and of making titrations with them. Indicators are also discussed, and their pH relations considered. Chap. II deals with "Accuracy and Associated Matters." Chap. III is on Acidimetry and Alkalimetry. Chap. IV deals with Oxidimetry in an up to date fashion, first teaching the elements of Oxidation-Reduction Potential and then applying them to the methods used. Chap. V treats of Iodimetry as a special case of oxidation-reduction titration. Chap. VI studies Precipitation Processes and the final Chap. VII gives A Synopsis of Volumetric Determinations.

It would appear to the reviewer that this is a most useable little text. Its psychology of teaching seems to be excellent. We note that "the volumetric technique is introduced as required" a most excellent way of doing. Much that is recent is introduced in the way of indicators and of methods. Bruhns' estimation of copper, the direct determination of iron by the method of Hahn & Windisch and the estimation of persulphate by Kurtenacker & Kubina may be mentioned. The author has the characteristic attitude of the good teacher in stressing the principles of chemistry in their applications to the work in hand.

F. B. WADE

Plane Trigonometry, by Cecil A. Ewing, Head of the Mathematics Department in the Tome School, Port Deposit, Maryland. Pages xii plus 162. $14.5 \times 21 \times 1.8$ cm. 1933. McGraw-Hill Book Company, Inc., New York.

This book contains an arrangement of topics different from the usual practice in dealing with the subject of trigonometry. Approximately twenty per cent of the material is in the first chapter called Computation. Here the author has the student pass through various forms such as approximate measurements, abbreviated computations, logarithms, exponential equations, and the slide rule. On the basis of pages, more than 25 per cent of the book has been exhausted before solutions of right triangles are presented. Logically and psychologically according to most authors of texts in trigonometry these should appear earlier in the course than presented.

A feature on computational form, in the solution of oblique triangles, is presented which enables one to solve several problems by making use of the same "set-up." The size of the print used in these forms, however, is objectionable and could have been improved materially.

Fifty-seven per cent of the book has been absorbed with other material

before the author found it necessary to introduce the general angle and its trigonometric functions and their relations. Preceding the data on the general angle the writer has many problems on the solution of the oblique triangle that involve angles greater than 90°. It does not seem quite logical to present such problems before the basic development (the general angle) has been concluded.

In Chapter X, the last preceding his final chapter of review, the author has placed the graphical representations of the trigonometric functions and has titled the chapter "Some Additional Topics." One is to assume, undoubtedly, that the course may be carried, should one be rushed because of lack of time, without this knowledge. It seems that a splendid opportunity was overlooked when the topics of Chapter X were not developed simultaneously with the appropriate topics when the general angle was developed.

JOSEPH J. URBANCEK

Intelligence: Its Manifestations and Measurement, by Paul L. Boynton, George Peabody College for Teachers, New York: D. Appleton & Co., 1933. Pp. 466.

It is not easy to discuss the topic of intelligence without fear of contradiction. Smuggled into scientific psychology from our folklore, the term *intelligence* has offered great opposition to all those who dared to define it. One who undertakes to write a whole book on the subject surely is not planning to do without criticism.

Professor Boynton's definition of intelligence must be attacked as orthodox and excessively biological. Psychologists are showing a persistent tendency away from an hereditary interpretation of intelligent and, for that matter, of any other kind, of behavior. To speak of intelligence therefore as dependent on the heredity of the individual only because intelligent activity is "part and parcel of cerebral activity" is like saying that a cat is a cat because he is not a dog. Surely modern biology would not support Boynton in the claim that function of any kind may be inherited. And that, after all, is the issue at stake.

Another shortcoming of the book is the fact that the author does not include in it what every student of the subject, certainly every beginning student, wants to know. I mean a systematic presentation of the steps through which a test must pass before becoming standardized for use. One reason for this omission is possibly the fact that the *validity* of intelligence testing is not as easy to prove as is the *reliability* of standard tests.

My third criticism is offered with considerable reluctance. It has reference to the careless English in which the presentation of the material is couched. It is true that one need not be at one and the same time scientist and man of letters; yet whenever one aspires to recognition as an author of a text one must make sure of such details before releasing his printed work. There are those who, if not actually handicapped, will be less influenced by the text because of its occasional faulty English.

In spite of this difficulty however the book is eminently readable. It contains an excellent history of the intelligence testing movement. It follows a logical plan of work. It is critical of certain unproved assumptions with regard to intelligence. It contains a fine bibliography and abounds in concrete illustrations. It is, in short, pedagogically sound.

The finest points in the book are its emphasis on the socio-cultural influences in the development of intelligent behavior. Another valuable feature is the section dealing with the methods of interpreting test data. By no means the least feature of the book is the chapter containing de-

tailed instructions to mental testers. There is genuine need for this type of material in a text aiming to develop psychological technicians.

The book should be of use not only to psychologists however. Teachers will find it a useful guide to their understanding of the intelligence movement, its achievements, present problems, and future prospects.

MAURICE H. KROUT

Other Worlds, by Edwin Lincoln Moseley, Head of the Department of Biology, Ohio State Normal College. Cloth. Pages xi+230. 12×18.5 cm. 1933. D. Appleton and Company, 35 West 32nd Street, New York, N. Y. Price $2.00.

Everyone is interested in astronomy but few have the time and patience to do sufficient study to be able to read even an elementary textbook on the subject. Here is a book that will answer many of your questions and you will enjoy every chapter. While it is not a juvenile book it will be interesting to the junior high school boy or girl as well as to the adult layman. The author, whose special field is biology, here writes on his hobby. It is not merely a book of facts about meteors, comets, planets, stars, constellations and nebulae, but the reader is told how these facts are determined, what instruments are used, and what information each contributes. A chapter discusses the theories of the origin of the earth and the other planets. The final chapter gives the conjectures and evidence relating to the question repeatedly asked: "Are there creatures like ourselves in other worlds?"

G. W. W.

A Textbook of Physics, Vol. I. Mechanics by E. Grimsehl, edited by R. Tomaschek, University of Marburg. Cloth. Pages xii+433. 14.5×22 cm. 1932. Messrs. Blackie and Son, Limited, 50 Old Bailey, London, E.C. 4. Price 15s. net.

This is the first volume of a translation of the seventh edition of a famous German textbook of physics which has been revised and modernized by Professor R. Tomaschek of Marburg and translated by L. A. Woodward.

The book is much more elaborate and somewhat more difficult than most American texts for general physics classes, and gives a more detailed treatment of each topic. A knowledge of the calculus is presupposed. Among the topics particularly useful in supplementing the ordinary textbook and deserving especial mention are those on the motion of a top, the path and motion of a projectile, and Chapter IX on the flow of liquids and gases. Since it is the custom in our colleges and universities to give only a year to general physics it is not likely that this set of books will be widely adopted for class use, but they should be in every science library for supplementary study and reference. High school teachers will find much help in answering some of the practical questions on airships and flight, the planets, gravitational fields, stability, inertia, and many other perplexing topics.

G. W. W.

Projective Differential Geometry of Curves and Surfaces, by Ernest Preston Lane, Professor of Mathematics in the University of Chicago. Cloth. Pages xi+321. 16.5×24.5 cm. 1932. The University of Chicago Press, Chicago, Illinois. Price $4.00.

Projective differential geometry is a recently developed phase of differential geometry. Professor E. J. Wilczynski was the founder of the science and wrote in English (1906) the first book ever published on the subject. The present book on this subject is the second one written in the English language. The book has been written for the purpose of coordinating the

investigations that have been carried on by many mathematicians in many different countries and to furnish a suitable text for beginners in this field of geometry.

J. M. KINNEY

The Development of Physical Thought, by Leonard B. Loeb, Professor of Physics, University of California, and Arthur S. Adams, Professor of Mechanics, Colorado School of Mines. Pages xiv+648. 15×22.5 cm. 1933. John Wiley and Sons, Inc. New York. Price $3.75 net.

This book presents a survey of physical science for college students. It is developed so as to bring out the manner in which fundamental physical concepts were gradually evolved and developed. The mathematics used is limited in most cases to high school algebra and geometry. Great emphasis is placed on the method of science, that of controlled quantative investigation. The book is not superficial in character, nor does it aim to popularize science. The material presented is substantial foundation knowledge; it is primarily intended for students and teachers and for them it clarifies and unifies the subject in a remarkable manner.

For all science teachers, and especially for those who teach the physical sciences, in our high schools, this book presents a rare and valuable background. The field of science has grown so rapidly that teachers have found it difficult to be up-to-date and at the same time to avoid dispersion of ideas. This book synthesizes and modernizes the subject and thus gives the teacher a more thorough grasp of the essentials to teach. A thorough study of this book will be a fair substitute for a summer school course.

Part I consist of 54 pages of historical material; Part VI, the last division, consist of 157 pages on The Electrical Structure of Matter, and The New Physics. These two divisions present topics, new and old, and give the subject a background and viewpoint which should be most helpful to teachers. The following topics extending throughout the book are especially good:

The Rate of Increase of Scientific Knowledge
The Nature of Forces
Orbits and Energy
Heat Death
The Kinetic Interpretation of Specific Heat
Molecular Orbits and Condensation
The Nature of Dielectric Behavior
The Reality of Atomic Magnets and the Magneton
The Nature of Color
Conduction of Electricity in Gases

Advanced high school students can read this book with profit. Every library serving science students or teachers should contain this book. Highly recommended to teachers of physics or chemistry.

W. F. ROECKER

Science Problems of Modern Life, Book II, by Ellsworth S. Obourn, Head of the Science Department, John Borroughs School, Clayton, Missouri, and Ellwood D. Heiss, Head of the Science Department, State Teachers College, East Stroudsburgh, Pennsylvania. Pages v+184. Paper. 21×28 cm. 1933. Webster Publishing Company, 1808 Washington Avenue, St. Louis, Mo. Price $.42 net.

The general plan of this volume is the same as that of Book I which was reviewed in the June, 1933, issue. It is a textbook, work-book, and manual combined. The general science course is continued with the following units: The Relation of Our Earth to other Heavenly Bodies, Rocks and Soils of

the Earth, Life on the Earth, Electricity and How We Use It, How Man Communicates, and Travel and Transportation. Many excellent illustrations are used; the cuts are clearer than those in Book I. Learning results should be good with the use of this book. Laboratory or demonstration work is closely coordinated with the text; provision is made for wide reading on the part of the pupil; a high degree of mastery of the laws, principles and facts is expected; and the responsibility for learning is largely assumed by the pupil. Everything is provided for the student except a pencil or pen and the cost is relatively low. General Science teachers will profit greatly by studying the methods exemplified by this book.

W. F. ROECKER

Introductory Mathematics, by John Wayne Lasley and Edward Tankard Browne, Professors of Mathematics, University of North Carolina. Cloth. Pages xvi+439. 14.5×22.5 cm. 1933. McGraw-Hill Book Company, Inc., 330 West 42nd Street, New York. Price $2.75.

This book is designed for an introductory course in college mathematics. It contains material enough to provide from three to five hours of work for one year. The function idea is the organizing thread of the course. There are eight chapters arranged in the following order: The Linear Function; The Quadratic Function; Functions of Higher Degree; The Rate of Change of a Function; Functions Changing at a given Rate; Exponential and Logarithmic Functions; Trigonometric Functions; Applications of the Logarithmic and Exponential Functions to the Solution of Oblique Triangles.

The notions of the calculus are introduced in Chapters IV and V and used consistently throughout the text. Thus the student who makes this course a terminal course in mathematics is given an opportunity to see how the calculus is used in the sciences. The student who is preparing for future courses in mathematics is not hampered by the preparation he obtains in this course. It is the opinion of the reviewer that such a student has gained a distinct advantage in that he has been given practice in thinking in terms of the calculus almost a year earlier than he would have done had he pursued the classical course.

Textual matter is ample and well written. The student may thus read the discussions with ease and enjoyment.

J. M. KINNEY

Mathematical Excursions, by Helen Abbot Merrill, Professor of Mathematics, Emeritus, in Wellesley College, Wellesley, Mass. Cloth. xi+145. 13.5×19.5 cm. 1933. Helen A. Merrill, 6 Waban Street, Wellesley, Massachusetts. Price $1.75.

The author's aim in writing this book is to offer some "side trips" in mathematics to people who have already traveled over the beaten paths of arithmetic, algebra, or geometry. "Those who are trying to help our young folks to see not only that mathematics is a useful tool and a mental discipline, but that hard work may be rare good fun, and that the subject widens out into fields of ever growing wonder and fascination, have generally learned what a large rôle entertaining problems may play."

There are fourteen chapters with the following headings: On Dividing; Different Ways of Writing Numbers; Multiplying without using the Multiplication Table; Mostly on Squares; The Charm of Decimals; Is this Formula True; Magic Squares; A Few Remarks on Measuring and Incommensurable Numbers; Some Facts about Pi; Geometric Arithmetic; Oddities of Numbers; Equations with many Answers; Drawing a Straight Line without a Ruler; The Impossible in Mathematics.

Many of the chapters end with sets of problems. The book is especially valuable for use in mathematics clubs.

J. M. KINNEY

Number the Language of Science, by Tobias Dantzig, Ph.D., Professor of Mathematics, University of Maryland; Lecturer on Mathematical Physics, U. S. Bureau of Standards. Second Edition. Revised. Pages viii+262. 14×21.5 cm. 1933. The Macmillan Company, 60 Fifth Avenue, New York. Price $3.50.

This book is a revision of the first edition of 1930. The revision has been confined to the correction of errors, clarification of some obscure passages, and the recasting of several paragraphs. There has been added a page of bibliographical notes suggesting further reading to those interested.

This book is not a technical mathematical treatise. It deals with ideas and not with methods. It is not a history; yet the historical method has been called into play in such a way as to give continuity to the story of the development of mathematics and to arouse interest on the part of the reader.

Such has been the popularity of the first edition that there have followed a special British edition, and French, German, and Russian translations. Every teacher of science and mathematics should read this delightful story. It should be found in every high school, college, and public library.

J. M. KINNEY

JOINT MEETING OF CENTRAL ASSOCIATION AND NATIONAL COUNCIL, CHICAGO, ILL., JULY 3, 1933

(51) OUT OF STATE REGISTRATION

Waters, Anne W. (Math.), Phillips H. S., Birmingham, Alabama
Waters, Hannah C. (Guest)
Weseen, Mildred J. (Math.), Analy Union H. S., Sebastopol, California
Fergus, T. V. (Math.), West H. S., Denver, Colorado
Fergus, Marie M. (Mrs.) (Eng.), Opportunity School, Denver, Colorado
Odell, Letitia R. (Math.), North H. S., Denver, Colorado
McDougle, Edith A. (Math.), Univ. of Delaware, Newark, Delaware
Bell, Addie Mae (Math.), Palm Beach H. S., W. Palm Beach, Florida
Crandall, G. H. (Math.), Culver Military Acad., Culver, Indiana
Kellam, C. E. (Math.), Washington H. S., East Chicago, Indiana
Swank, Orville M. (Math.), Froebel H. S., Gary, Indiana
Hildebrandt, Emanuel (Math.), DePauw Univ., Greencastle, Indiana
Brown, F. Douglass (Math.), Warren Central H. S., Indianapolis, Indiana
Thornton, Wilson (Math.), Central Sen. H. S., South Bend, Indiana
Shriner, Walter O. (Math.), Indiana S. T. C., Terre Haute, Indiana
Gaekle, Louise (Math.), Muscatine Jr. Coll., Muscatine, Iowa
Marm, Anna (Math.), Bethany Coll., Lindsborg, Kansas
Puterbaugh, Allen (Math.), Leitchfield, H. S., Leitschfield, Kentucky
Gregory, M. Cottell (Math.), Louisville Girl's H. S., Louisville, Kentucky
Bowers, Margaret A. (Math.), Elkton H. S., Elkton, Maryland
Sherman, S. P. (Mrs.) (Guest), Boston, Massachusetts
Bishop, Florence (Math.), Central H. S., Flint, Michigan
Hastings, Marie (Math.), Central H. S., Flint, Michigan
Loss, Nellie (Math.), Flint Sec. Schools, Flint, Michigan
Dritt, Sarah (Math.), Clayton H. S., Clayton, Missouri
Lowen, Letha (Math.), Lafayette H. S., St. Joseph, Missouri
Howard, Bess (Math.), Univ. City H. S., University City, Missouri
Brewer, David S. (Math.), Jordan, Montana, Bozeman, Montana
Eagle, Edwin (Math.), St. Regis, Montana, Bozeman, Montana
Scovil, Rudolph J. (Math.), Great Falls H. S., Great Falls, Montana
Beery, John R. (Math.), Merchantville, H. S., Merchantville, New Jersey
Orleans, Joseph B. (Math.), George Washington H. S., New York, New York
Betz, William (Math.), Rochester, New York
Burr, Irving W. (Math.), Antioch Coll., Yellow Springs, Ohio
Wigton, Grace (Math.), Senior High, Zanesville, Ohio
Dunlap, Mary (Math.), Junior High, Chickasha, Oklahoma
Foberg, J. A. (Math.), State Teachers Coll., California, Pennsylvania
Stutzenburg, Mary E. (Science), Univ. of Pa., Philadelphia, Pennsylvania
Demmer, Hugh L. (Math. & Sci.), Custer H. S., Custer, South Dakota
Woodruff, Fannie Mae (Math.), Bolton H. S., Brunswick, Tennessee
Cannon, Louise (Math.), Bartlett, Tenn., Covington, Tennessee
Bagley, Grace F. (Math.), George Wash. H., Danville, Virginia
Cox, Mary J. (Math.), Hollins Coll., Hollins, Virginia

Orr, W. G. (Math.), Lincoln High, Tacoma, Washington
Hart, W. W. (Math.), Univ. of Wisconsin, Madison, Wisconsin
Hartung, M. L. (Math.), Univ. of Wisconsin, Madison, Wisconsin
Crewes, Frances (Math.), Riverside H. S., Milwaukee, Wisconsin
Roecker, W. F. (Sience), Boys' Technical H. S., Milwaukee, Wisconsin
Watson, J. Harold (Math.), Oshkosh H. S., Oshkosh, Wisconsin
Neitzel, Anna L. (Math.), Wash. Park H. S., Racine, Wisconsin
Potter, Mary A. (Math.), Wash. Park H. S., Racine, Wisconsin

(27) Illinois Registration Outside Chicago

Gutekunst, Hans (Math.), Math Institute, Batavia
Berrs, Edna P. (Math.), J. Sterling Morton H. S., Cicero
McDonald, J. R. (Math.), J. Sterling Morton H. S., Cicero
Miller, Mabel I. (Math.), J. Sterling Morton H. S., Cicero
Herring, Annie M. (Guest), Lincoln Grove, Downers Grove
Innes, Frances C. (Math.), Dundee Comm. H. S., Dundee, Ill.
Peters, Mary A. (Math.), Elgin H. S., Elgin, Ill.
Arnold, Erma L. (Math.), Nichols Interm. S., Evanston
Hathaway, A. S. (Engin.), Coll. of Engineering, Evanston
Nash, M. Estelle (Math.), Evanston Twp. H. S., Evanston
Runge, Francis W. (Math.), Evanston Twp. H. S., Evanston
Stafford, Acenith V. (Math.), Evanston Twp. H. S., Evanston
Wood, Frank Edwin (Math.), Northwestern Univ., Evanston
Schreiber, Edwin W. (Math.), State Teachers Coll., Macomb
Hildebrandt, Martha (Math.), Proviso Twp. H. S., Maywood
Seybold, Anice (Math.), Monticello Com. H. S., Monticello
Lindberg, Jean R. (Math.), Mount Morris Pub. S., Mount Morris
Austin, C. M. (Math.), Oak Park H. S., Oak Park
Chandler, Harvey W. (Math.), Oak Park H. S., Oak Park
Johnson, Elsie Parker (Math.), Oak Park H. S., Oak Park
Weckel, Ada L. (Science), Oak Park H. S., Oak Park
Woodruff, R. S. (Math.), Oak Park H. S., Oak Park
Rusch, O. F. (Math. & Sci.), Concordia Tea. Coll., River Forest
Taylor, S. Helen Dr. (Math.), Univ. of Illinois, Urbana
Dady, Bess (Math.), Waukegan Twp. H. S., Waukegan
Dady, Margaret (Math.), Waukegan Twp. H. S., Waukegan
Routsong, R. C., (Guest) (Math.), New Twp. H. S., Winnetka

(86) Chicago Registration

Bartky, Walter (Math.), University of Chicago
Bibb, Samuel (Math.), Armour Institute
Billings, H. C. (Math.), Austin High School
Bower, Julia Wells (Math.), University of Chicago
Breslick, E. R. (Educ.), University of Chicago
Cable, Wickliffe I. (Math.), Austin High School
Carroll, Lauretta M. (?), Bryn Mawr School
Christman, Laura E. (Math.), Senn High School
Clark, W. H. (Math.), Crane Jr. College
Clevenger, Mellie C. (Math.), Lane Technical High School
Colwell, Lewis W. (?), Sullivan Junior High School
Conner, S. J. A. (Math.), Harrison High School
Conner, S. J. A. (Mrs.) (?)
Davis, James E. (Math.), Central Y.M.C.A. College
Davis, R. E. (Science), Lane Tech.
Doyle, M. V. (Math.), Manley Junior High
East, Margaret K. (Math.), Carl Schurz High School